REPORT NO. DRXTH-AS-CR-82170
(ESG-82-38)

4034 1

COPY 1

Copy 2

FINAL REPORT
FOR THE

ALABAMA ARMY AMMUNITION PLANT LEASEBACK AREA DECONTAMINATION OPERATIONS PROJECT

PART I — EXECUTIVE SUMMARY

ANTHONY F. LILLIE

ROCKWELL INTERNATIONAL
ATOMICS INTERNATIONAL DIVISION
ENERGY SYSTEMS GROUP
8900 DE SOTO AVENUE
CANOGA PARK, CALIFORNIA 91304

SEPTEMBER 1982

DISTRIBUTION UNLIMITED

PREPARED FOR: U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY
ABERDEEN PROVING GROUND, MARYLAND 21010

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DRXTH-AS-CR-82170	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* Final Report for the Alabama Army Ammunition Plant Leaseback Area Decontamination Operations Project		5. TYPE OF REPORT & PERIOD COVERED Final Report Sep 1981 - Dec 1982 6. PERFORMING ORG. REPORT NUMBER ESG-82-38
7. AUTHOR(s) Anthony F. Lillie		8. CONTRACT OR GRANT NUMBER(s) DAAK11-81-C-0094
9. PERFORMING ORGANIZATION NAME AND ADDRESS Rockwell International, Energy Systems Group 8900 Desoto Avenue Canoga Park, CA 91304		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Toxic and Hazardous Materials Agency ATTN: DRXTH-AS Aberdeen Proving Ground, MD 21010		12. REPORT DATE Sep 82 13. NUMBER OF PAGES 153
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Distribution Unlimited
Cleared for public release.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Decontamination and cleanup operations, explosive residues, nitrocellulose (NC), 2,4 and 2,6 Dinitrotoluene (DNT), smokeless powder, demolition, Leaseback Area, Alabama Army Ammunition Plant, and Installation Restoration.

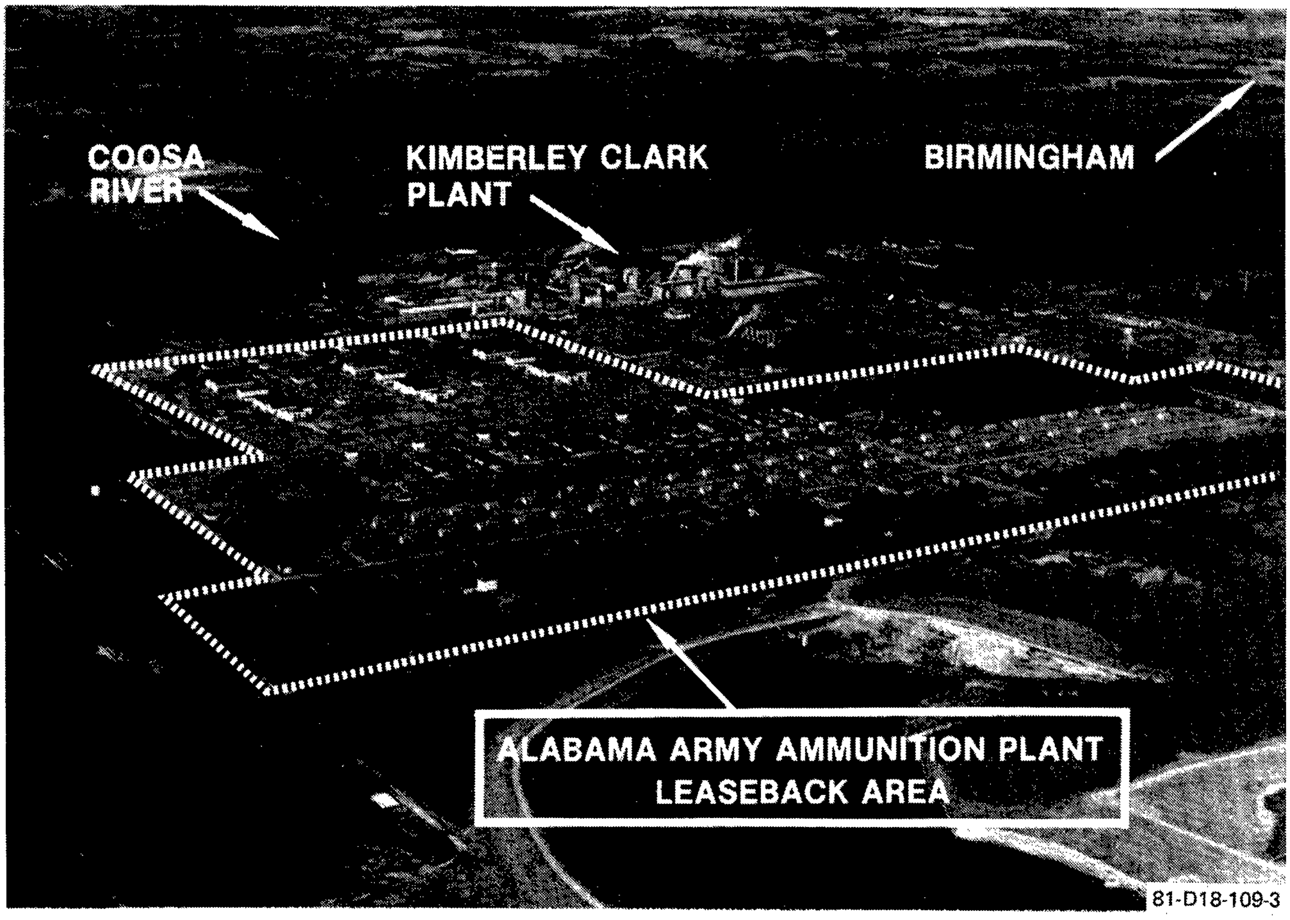
20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The decontamination/cleanup of the Leaseback Area of the Alabama Army Ammunition Plant (AAAP) was conducted in three phases. During Phase I, verification tests were conducted to demonstrate the effectiveness of various decontamination and cleanup methods. Standing Operating Procedures (SOPs) required to conduct the decontamination/cleanup operations were prepared during Phase II. Actual decontamination/cleanup operations were conducted during Phase III. The decontamination/cleanup at the 272-acre Leaseback Area of AAAP consisted of

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

decontamination of explosive/explosive residues mainly consisting of nitrocellulose (NC) and 2,4 and 2,6 Dinitrotoluene (DNT) which had resulted from production operations at the plant. Prior to decontamination operations 21,000 cubic feet of friable asbestos, 186 PCB-contaminated electrical switches, and 789 mercury-containing components were removed and disposed of according to approved Federal and State of Alabama regulations. A total of 193 buildings, 407 tanks, 445 sumps, nine miles of industrial sewer system, and many miles of process lines were decontaminated to meet established cleanness criteria so that the Leaseback Area could be released to Kimberly Clark Paper Company for industrial use. An extensive sampling, analysis, and data management program was implemented to allow certification of the effectiveness of the decontamination operations.


COOSA
RIVER
KIMBERLEY CLARK
PLANT
BIRMINGHAM
ALABAMA ARMY AMMUNITION PLANT
LEASEBACK AREA
81-D18-109-3

CONTENTS

CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

1.0 INTRODUCTION

The Alabama Army Ammunition Plant (AAAP), formerly the Alabama Ordnance Works, was operated during World War II to produce nitrocellulose (NC); single-base smokeless powder; 2,4,6 trinitrotoluene (2,4,6 TNT); 2,4 and 2,6 dinitrotoluene (2,4 DNT and 2,6 DNT); and trinitrophenylmethylnitramine (tetryl). Plant operations ceased immediately following World War II, and the plant reverted to standby status. After the termination of operations, the prime contractor (DuPont) decontaminated the surfaces of machinery, equipment, buildings, and ground areas.

A rehabilitation program was conducted in the mid-1950s to improve and update the three NC lines, three of the 2,4,6 TNT lines, and one DNT line to incorporate the latest production developments and techniques. The rehabilitation program was terminated before completion. The rehabilitated lines were never put into operation. In 1973, the Department of the Army declared AAAP excess to its needs.

In 1977, a 1,354 acre parcel was sold to the Kimberly Clark Corporation. Contained within the parcel were the NC and smokeless powder manufacturing areas. To allow the government to remove equipment and decontaminate these manufacturing facilities for industrial use, an area comprising 272 acres was leased back to the government until August 1983 (the so-called Leaseback Area).

The United States Army Toxic and Hazardous Materials Agency (USATHAMA) is charged with the responsibility of defining, quantifying, and decontaminating the explosives and industrial safety hazards resulting from previous manufacturing and maintenance operations on excessed Army property. An environmental survey of the Leaseback Area was conducted in 1979 and 1980 by Environmental Science and Engineering, Inc. (ESE) to define and quantify the contamination in the area. Based on the results of that survey, a request for proposal was issued in May 1981 for decontamination of the Leaseback Area. In September

1981, a 15-month, $5.1 million contract (DAAK11-81-C-0094) for this decontamination effort was awarded to Rockwell International, Energy Systems Group (hereafter referred to as Rockwell).

The contract was completed approximately 2 months ahead of schedule and 5% under contract value. Approximately 21,000 ft^3 of friable asbestos was removed and disposed of in accordance with Occupational Safety and Health Administration (OSHA) and State of Alabama regulations. A total of 186 polychlorinated biphenyl (PCB) contaminated items and 789 components containing mercury were removed, packaged, transported, and disposed of* at an approved hazardous waste disposal facility. A total of 193 buildings, nine miles of industrial sewer system, 407 tanks, 445 sumps, and many miles of process piping have been decontaminated; the structures have been demolished; and the rubble has been removed from the Leaseback Area. Data were obtained and recorded to certify the effectiveness of the decontamination operations.

This report (i.e., Part I of the final report) summarizes the project and important conclusions drawn from the project. Detailed certifications as to the effectiveness of the decontamination are presented in Part II of the final report.

*EPA generator number ALD98604003

2.0 BACKGROUND

2.1 HISTORY OF AAAP

The Alabama Army Ammunition Plant (AAAP), formerly the Alabama Ordnance Works (Figure 1), is located in Talladega County, Alabama, approximately four miles north of Childersburg and 40 miles southeast of Birmingham. The plant, established in 1941 on 13,233 acres of land near the confluence of Talladega Creek and the Coosa River, is located on level to gently rolling terrain largely suited to pasture and timber.

The initial construction contract for the NC and smokeless powder production facilities (the so-called Leaseback Area) was awarded to E. I. duPont deNemours and Company on 23 January 1941. The contract called for the design and construction of NC manufacturing units, smokeless powder manufacturing units, and alcohol rectification facilities, along with support facilities such as power and water supplies, storage magazines, change houses, and other buildings, facilities, and equipment. Construction of the NC and smokeless powder manufacturing facilities was completed on 31 January 1942.

In August 1941, the government contracted with duPont to construct a second plant at AAAP for the manufacture of 2,4,6 TNT, DNT, and tetryl. This plant was constructed in the northern section of AAAP (see Figure 2). The major portion of the construction of the 2,4,6 TNT plant was completed in March 1943. At the height of construction of the NC/smokeless powder production facilities, over 19,000 people were employed. Over 8,000 people were employed at peak construction of the 2,4,6 TNT production facilities.

Peak production during World War II was approximately 8,000 tons/month of NC/smokeless powder, 11,000 tons/month of 2,4,6 TNT, and 1,200 tons/month of tetryl.

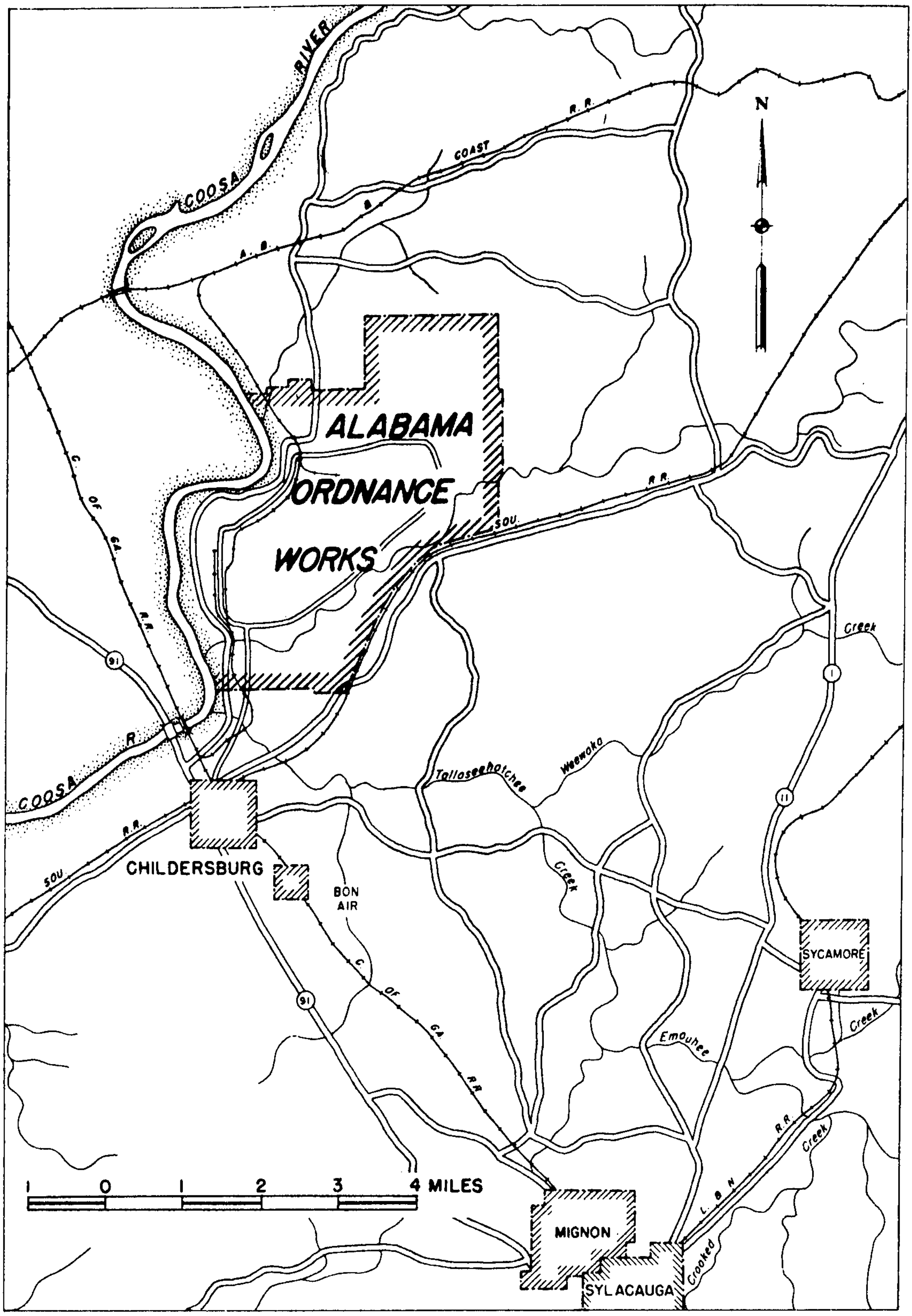
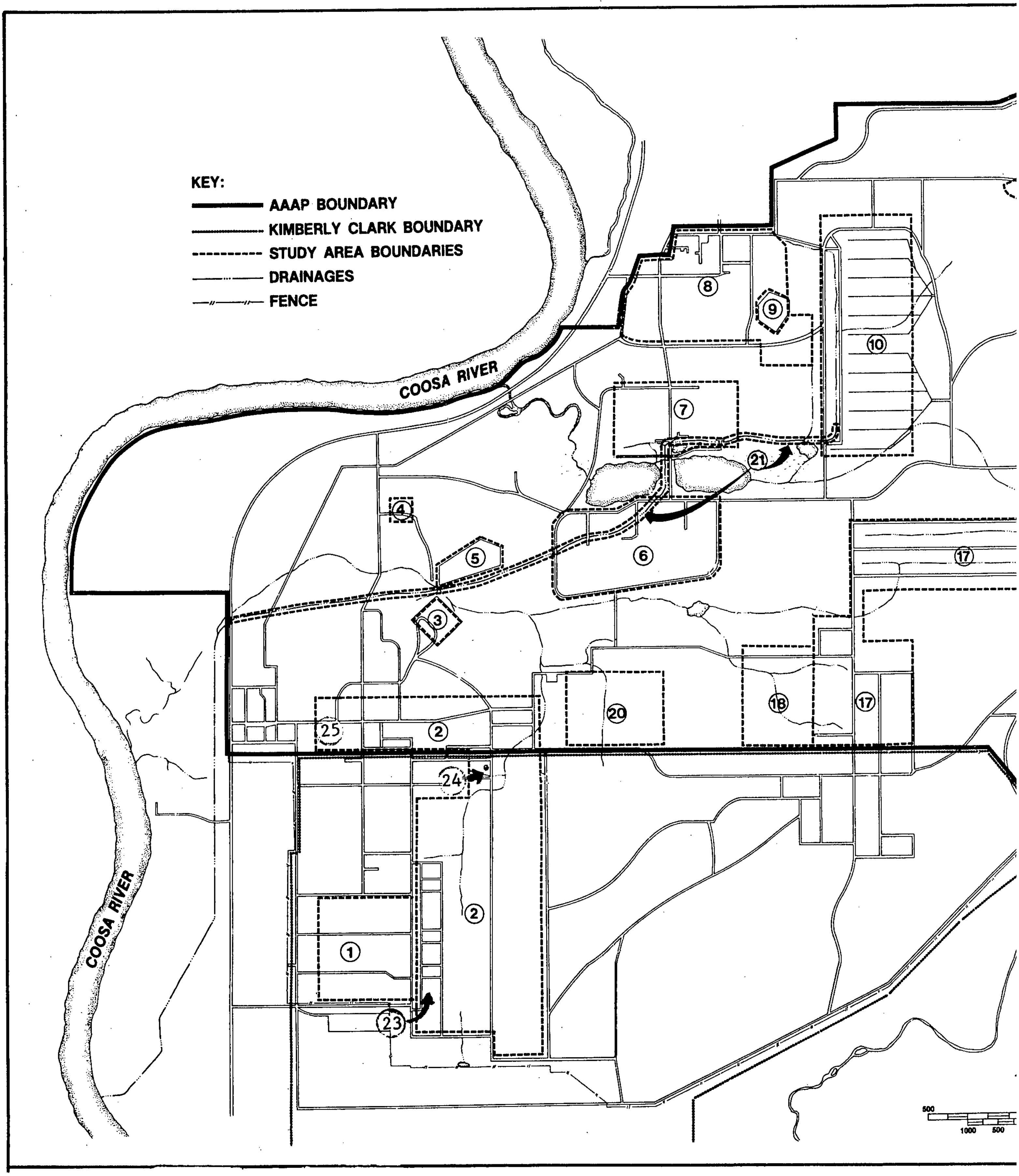
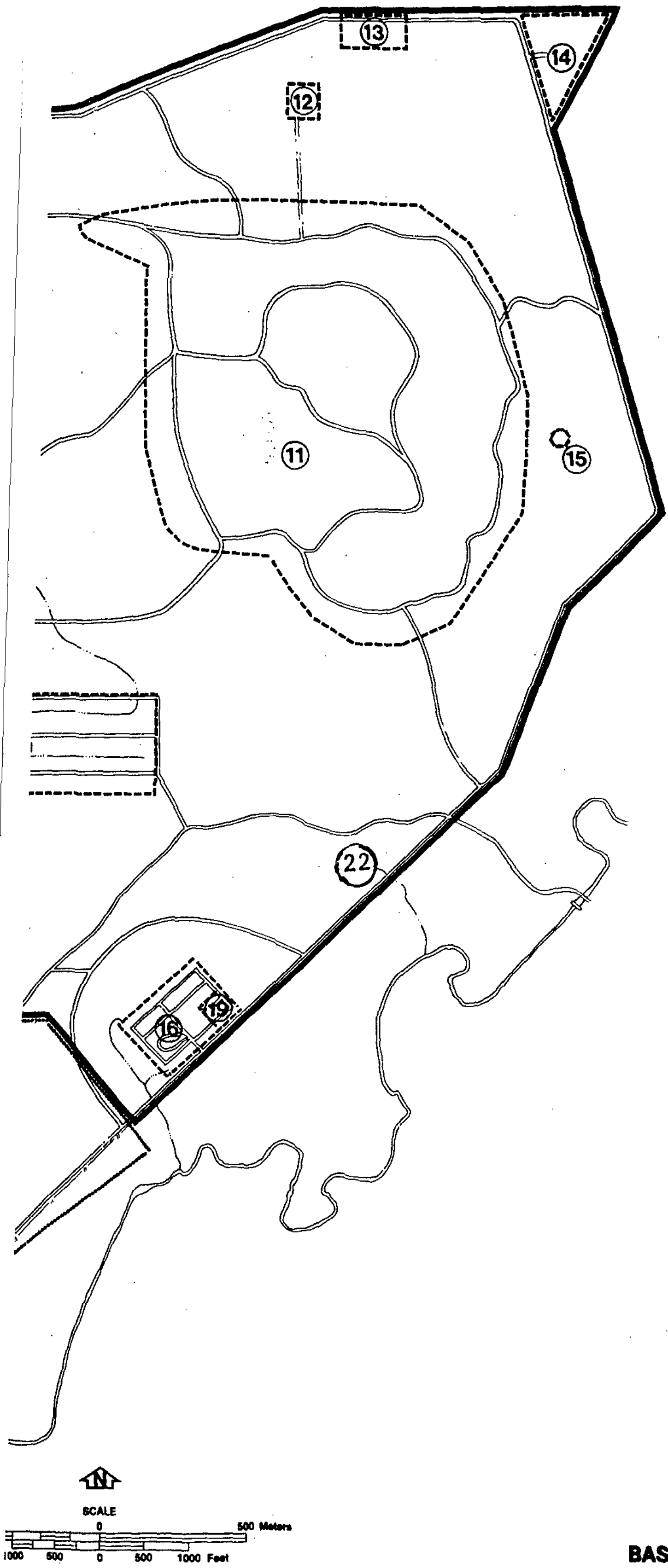


Figure 1. Vicinity Map of Alabama Ordnance Works


KEY:
AAAP BOUNDARY
KIMBERLY CLARK BOUNDARY
STUDY AREA BOUNDARIES
DRAINAGES
FENCE
COOSA RIVER
COOSA RIVER
1
2
2
3
4
5
6
7
8
9
10
17
17
18
20
21
23
24
25
500
1000
500



KEY

STUDY AREA	DESCRIPTION
1	NITROCELLULOSE MANUFACTURING AREA
2	SMOKELESS POWDER MANUFACTURING AREA
3	INERT MATERIAL BURNING GROUND/SANITARY LANDFILL
4	MANHATTAN PROJECT AREA
5	RED-WATER STORAGE BASIN
6	SOUTHERN TNT MANUFACTURING AREA
7	NORTHERN TNT MANUFACTURING AREA
8	ACID/ORGANIC MANUFACTURING AREA
9	ANILINE SLUDGE BASIN
10	TETRYL MANUFACTURING AREA
11	MAGAZINE AREA
12	OLD BURNING GROUND
13	SMALL ARMS BALLISTICS RANGE
14	CANNON RANGE
15	OLD WELL
16	FLASHING GROUND
17	PROPELLANT SHIPPING AREA
18	BLENDING TOWER AREA
19	LEAD FACILITY
20	RIFLE POWDER FINISHING AREA
21	RED-WATER DITCH
22	DEMOLITION LANDFILL
23	BURIAL TRENCH (BUILDING 217-A)
24	OIL DUMP SITE (BUILDING 722-D)
25	ASBESTOS LANDFILL

BASE MAP COURTESY OF: U.S. Army. Toxic and Hazardous Materials Agency
SOURCE: Environmental Science and Engineering Inc., 1980

2

Figure 2. AAAP Site Layout

Plant operations were terminated in August 1945, immediately following the end of World War II. The plant reverted to a standby status. Following the termination of operations, duPont decontaminated the surfaces of machinery, equipment, buildings, and ground areas. On completion of these activities, the government released duPont from the facility in September 1946.

In January 1954, the government entered into a contract with Liberty Powder Defense Corporation, a subsidiary of Olin Mathieson Chemical Corporation. This contract provided for maintenance of the plant, design engineering, and consultant services in connection with the plant rehabilitation, which took place from April 1955 through October 1957.

The plant rehabilitation contracts, negotiated by the Mobile District of the Corps of Engineers with Associated Contractors and the Rust Engineering Company, called for rehabilitation of the three NC lines, three of the TNT lines, and one DNT line, plus supporting facilities. The work was terminated before completion. Peak employment during the rehabilitation work occurred in January 1957, when approximately 3,300 people were employed.

The plant was maintained by the Liberty Power Company on standby status until 1975. Meanwhile, in 1973, the Department of the Army declared the plant excess to its needs. In 1977, a 1,354-acre parcel containing the NC and smokeless powder manufacturing areas was sold to Kimberly Clark. To allow the government to remove equipment and to decontaminate these manufacturing facilities for industrial use, a 272-acre area was leased back by Kimberly Clark to the government until August 1983. This is the so-called Leaseback Area.

Several other parcels of the original property have been sold, and today AAAP covers approximately 5,000 acres (excluding the Leaseback Area).

2.2 CONTAMINATION SURVEY OF THE LEASEBACK AREA

USATHAMA, which is charged with the responsibility for defining, quantifying, and decontaminating the explosives and industrial safety hazards resulting from previous manufacturing and maintenance operations on excessed Army property, contracted with Environmental Science and Engineering, Inc. (ESE) to conduct an environmental survey of AAAP, including the Leaseback Area. ESE conducted the survey in 1979 and 1980 and confirmed the presence of NC and smokeless powder contamination in the Leaseback Area. The contamination levels were very low in buildings and equipment due to the decontamination operations performed by duPont immediately following the cessation of operations after World War II. Nevertheless, decontamination was required before the property could be returned to Kimberly Clark. Furthermore, the ESE survey identified the presence of substantial amounts of friable asbestos in the Leaseback Area buildings, which had to be removed prior to decontamination operations. In the northeastern portion of the Leaseback Area, propellant grains were found at the outflow of the industrial sewer system serving the tray dry houses (the 237 buildings), which are located in that area. Contamination was also found in the industrial sewer system throughout the Leaseback Area.

As a result of these findings, USATHAMA prepared a statement of work resulting in a request for proposal (RFP) to decontaminate the Leaseback Area. The RFP was issued in May 1981. Rockwell was selected to perform the decontamination. Contract DAAK11-81-C-0094 for the decontamination operations was awarded on 25 September 1981.

2.3 DECONTAMINATION PROJECT FOR THE LEASEBACK AREA

The contract called for Rockwell, acting as an independent contractor and not as an agent of the government, to provide the necessary personnel, facilities, equipment, and materials required to accomplish the following:

- Prepare, and submit to the government, technical and management plans and standing operating procedures (SOPs) defining the approach to be taken to accomplish the decontamination of the Leaseback Area.
- Conduct tests and test burns on a limited number of facilities and other contaminated areas within the Leaseback Area to verify the proposed decontamination methods and procedures.
- Establish and implement a written field and laboratory quality control (QC) program in accordance with the USATHAMA QA Program requirements to assure the reliability and cost effective analysis of all data generated in support of the project.
- Acquire, maintain, and report all field and laboratory data in a manner consistent with the USATHAMA Data Management System.
- Decontaminate all contaminated areas in accordance with the technical and management plans, SOPs, and contract requirements.
- Provide certification that the decontamination has been accomplished.
- Prepare and submit to the government a final report covering all the decontamination operations conducted. The final report shall include all documentation and testing results which confirm decontamination of the Leaseback Area.

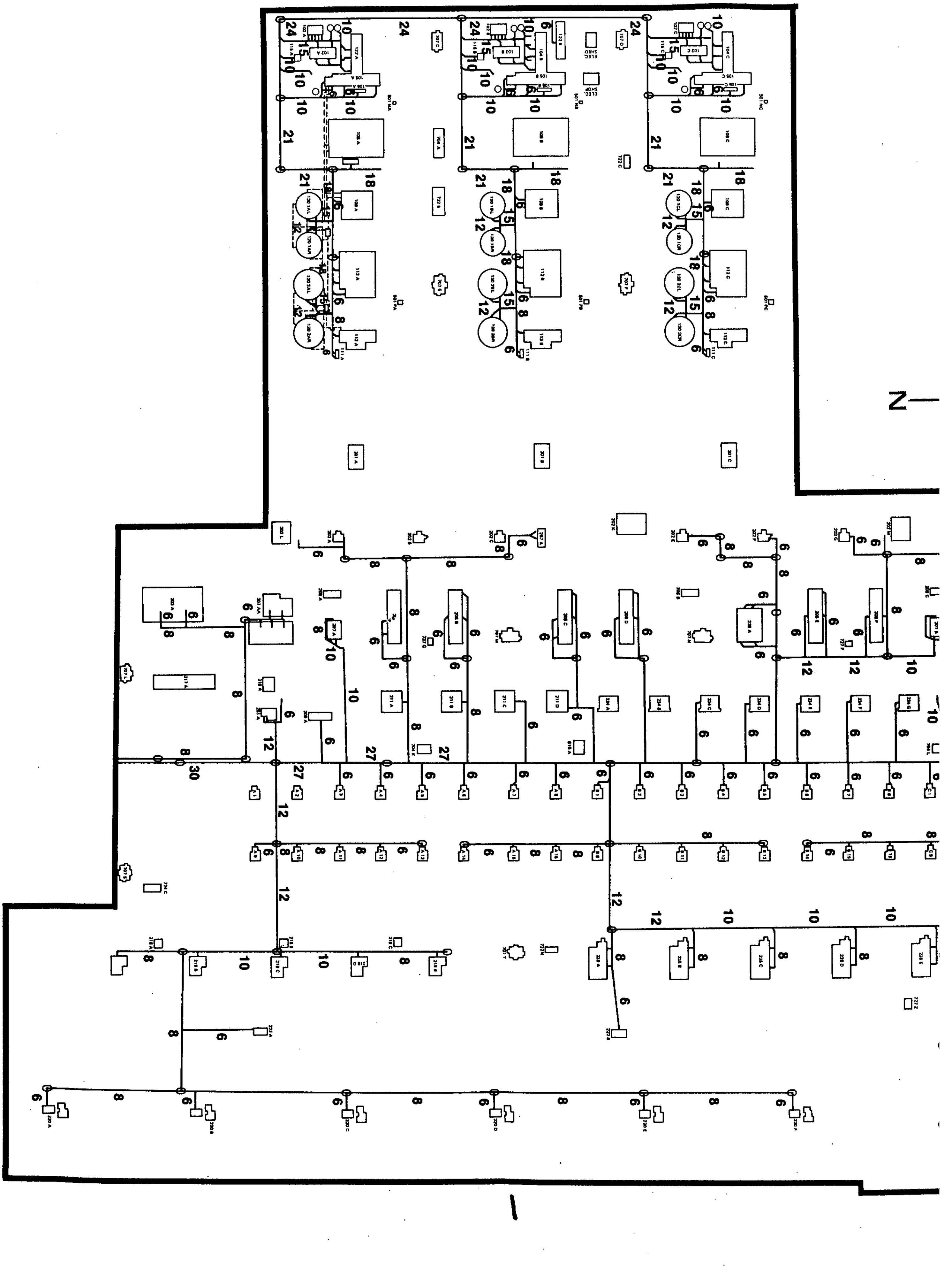
3.0 DECONTAMINATION PROJECT OVERVIEW

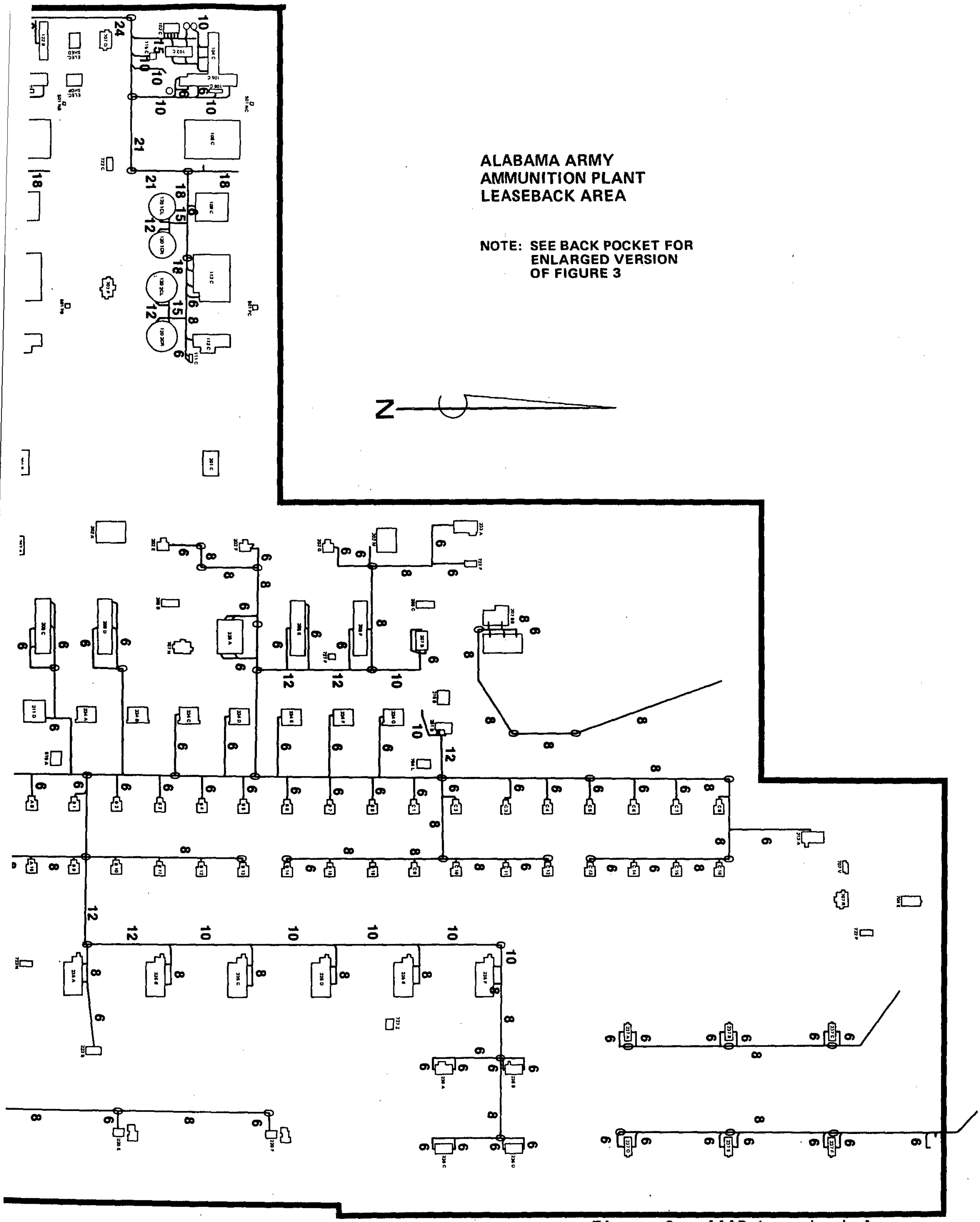
3.1 SCOPE OF THE PROJECT

The scope of the AAAP Decontamination Operations Project involved the removal and/or decontamination of explosive residues and other industrial safety hazards located within the 272-acre Leaseback Area of the AAAP (see Figure 3). The explosive residue contaminants consisted of NC, DNT, and single-base smokeless powder that resulted from production operations at the plant. Before beginning the decontamination operations, it was necessary to remove 21,000 ft^3 of friable asbestos, 186 electrical switches containing PCBs, and 789 components containing mercury from the buildings and outside areas in the Leaseback Area. During the project, 193 buildings, 407 tanks, and 445 sumps were decontaminated; nine miles of industrial sewer system were excavated and decontaminated; and many miles of process lines contained within the facilities were decontaminated. Propellant grains from the 237 series buildings and from the sewer outflow region in the northeastern portion of the Leaseback Area and adjoining GSA area were removed and burned. All operations were conducted in accordance with USATHAMA-approved SOPs and the appropriate federal and State of Alabama hazardous waste management regulations.

An extensive sampling, analysis, and data management program was implemented to obtain the data necessary to allow certification of the effectiveness of the decontamination operations. Over 5,000 samples were analyzed during the project. These data are presented in supporting documentation (see Figure 4).

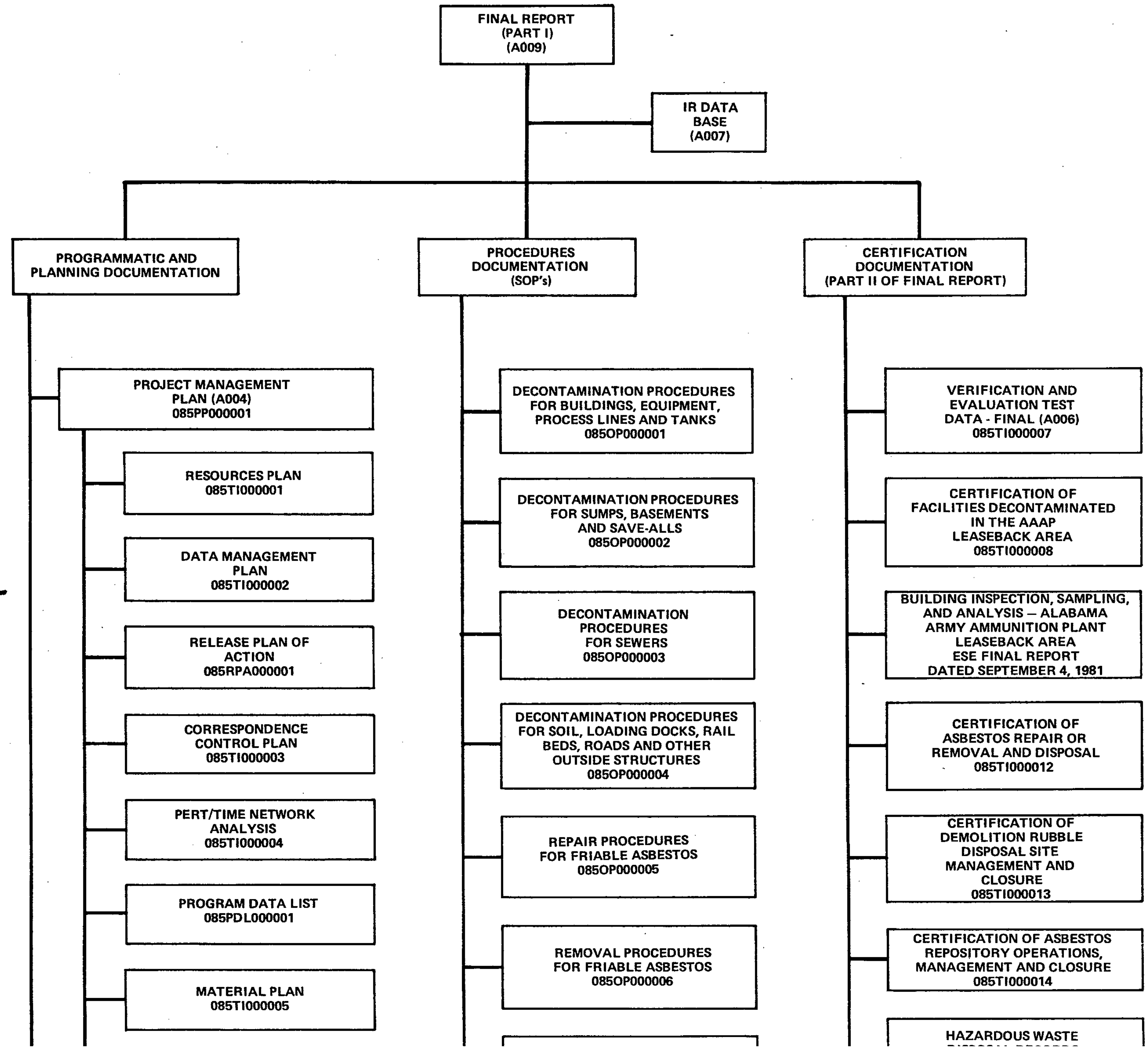
Following decontamination, the structures were demolished to the slab, and the rubble was removed to a state-approved rubble disposal area (see Figure 5) located just north of the Leaseback Area on AAAP property. Salvageable scrap metal was set aside for future sale by the government in a

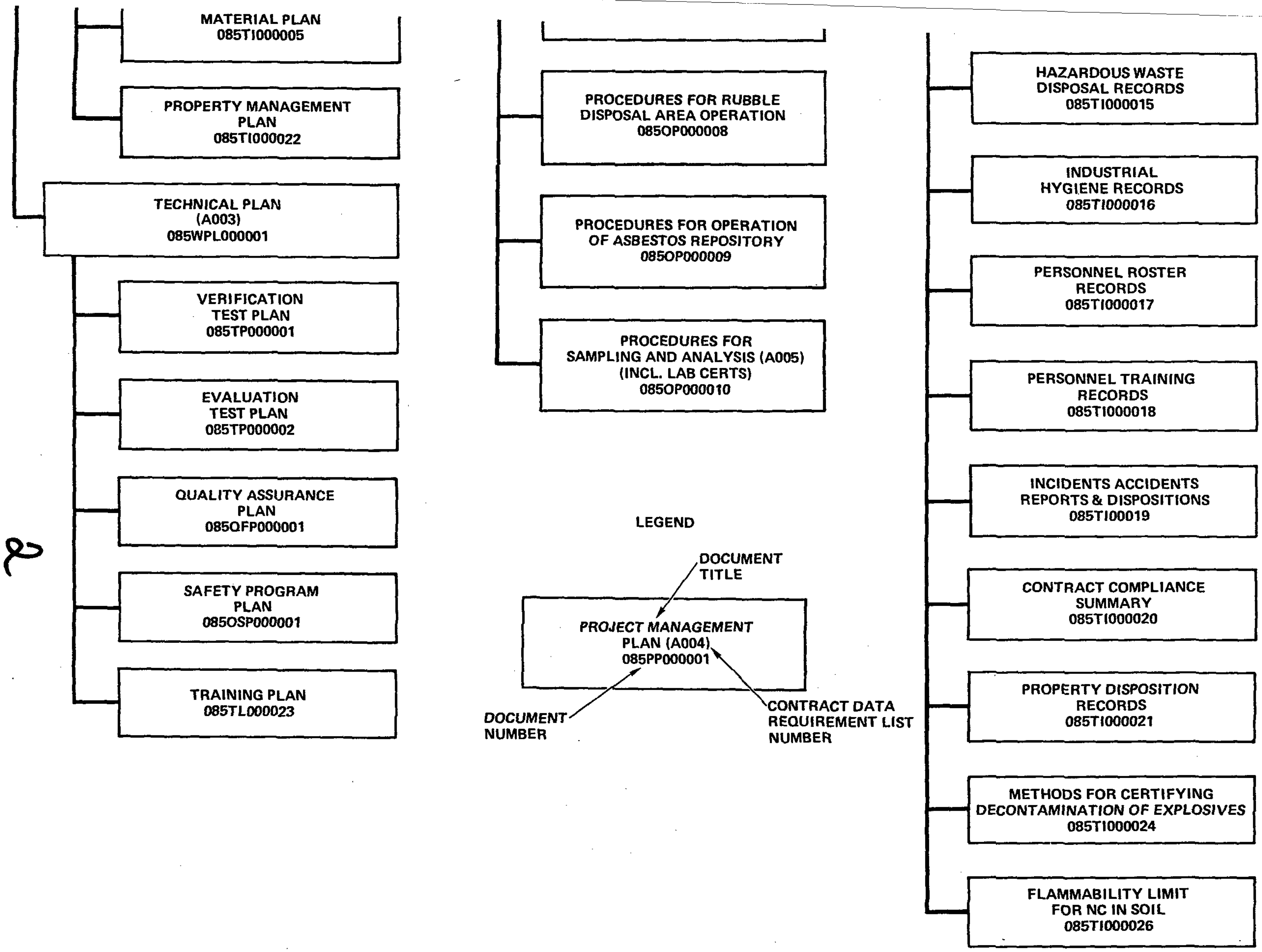




2

Figure 3. AAAP Leaseback Area


FINAL REPORT (PART I) (A009)
IR DATA BASE (A007)
PROGRAMMATIC AND PLANNING DOCUMENTATION
PROCEDURES DOCUMENTATION (SOP's)
CERTIFICATION DOCUMENTATION (PART II OF FINAL REPORT)
PROJECT MANAGEMENT PLAN (A004) 085PP000001
RESOURCES PLAN 085TI000001
DATA MANAGEMENT PLAN 085TI000002
RELEASE PLAN OF ACTION 085RPA000001
CORRESPONDENCE CONTROL PLAN 085TI000003
PERT/TIME NETWORK ANALYSIS 085TI000004
PROGRAM DATA LIST 085PDL000001
MATERIAL PLAN 085TI000005
DECONTAMINATION PROCEDURES FOR BUILDINGS, EQUIPMENT, PROCESS LINES AND TANKS 085OP000001
DECONTAMINATION PROCEDURES FOR SUMPS, BASEMENTS AND SAVE-ALLS 085OP000002
DECONTAMINATION PROCEDURES FOR SEWERS 085OP000003
DECONTAMINATION PROCEDURES FOR SOIL, LOADING DOCKS, RAIL BEDS, ROADS AND OTHER OUTSIDE STRUCTURES 085OP000004
REPAIR PROCEDURES FOR FRIABLE ASBESTOS 085OP000005
REMOVAL PROCEDURES FOR FRIABLE ASBESTOS 085OP000006
VERIFICATION AND EVALUATION TEST DATA - FINAL (A006) 085TI000007
CERTIFICATION OF FACILITIES DECONTAMINATED IN THE AAAP LEASEBACK AREA 085TI000008
BUILDING INSPECTION, SAMPLING, AND ANALYSIS – ALABAMA ARMY AMMUNITION PLANT LEASEBACK AREA ESE FINAL REPORT DATED SEPTEMBER 4, 1981
CERTIFICATION OF ASBESTOS REPAIR OR REMOVAL AND DISPOSAL 085TI000012
CERTIFICATION OF DEMOLITION RUBBLE DISPOSAL SITE MANAGEMENT AND CLOSURE 085TI000013
CERTIFICATION OF ASBESTOS REPOSITORY OPERATIONS, MANAGEMENT AND CLOSURE 085TI000014
HAZARDOUS WASTE



2

Figure 4. Project Documentation Tree

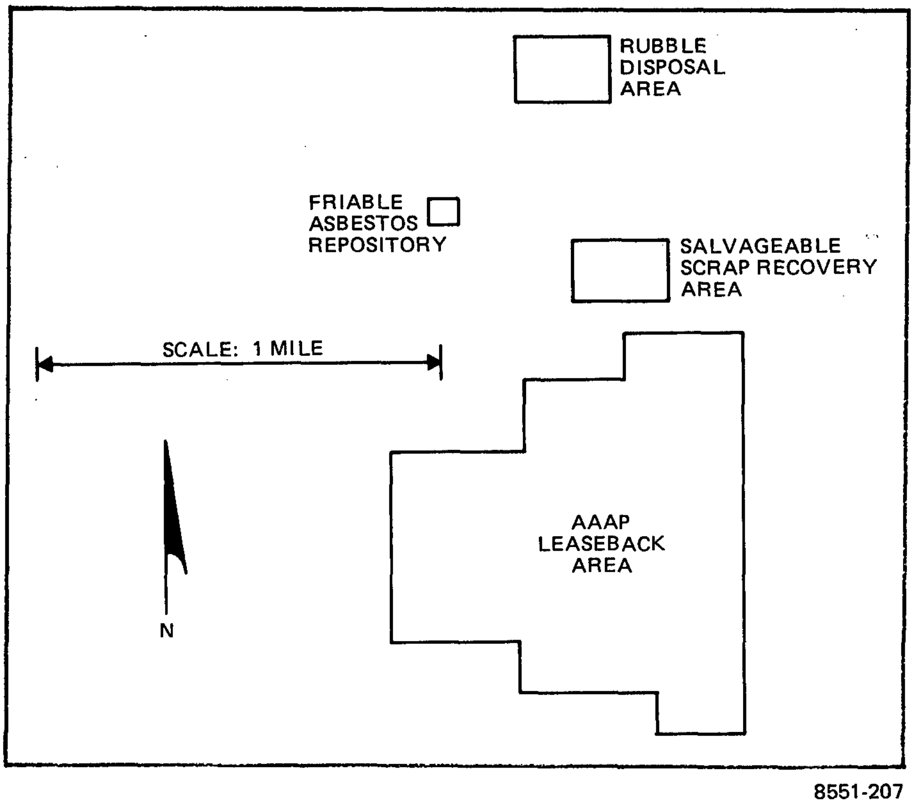


Figure 5. Location of Repository and Rubble Disposal Sites

scrap recovery area (Figure 5), also located just north of the Leaseback Area on AAAP property. A joint inspection and acceptance of the completed Leaseback Area was then conducted by representatives of both Rockwell and USATHAMA prior to final completion of the contract.

3.2 OVERALL TECHNICAL APPROACH

The technical approach used to accomplish the AAAP Leaseback Area decontamination operations is summarized in Figure 6. Briefly, there were two major phases to the project: project planning, generation of SOPs and verification testing, followed by actual decontamination operations and certification.

3.2.1 Project Planning

Two major documents formed the basis for planning the overall project. These two documents — the Project Management Plan and the Technical Plan —

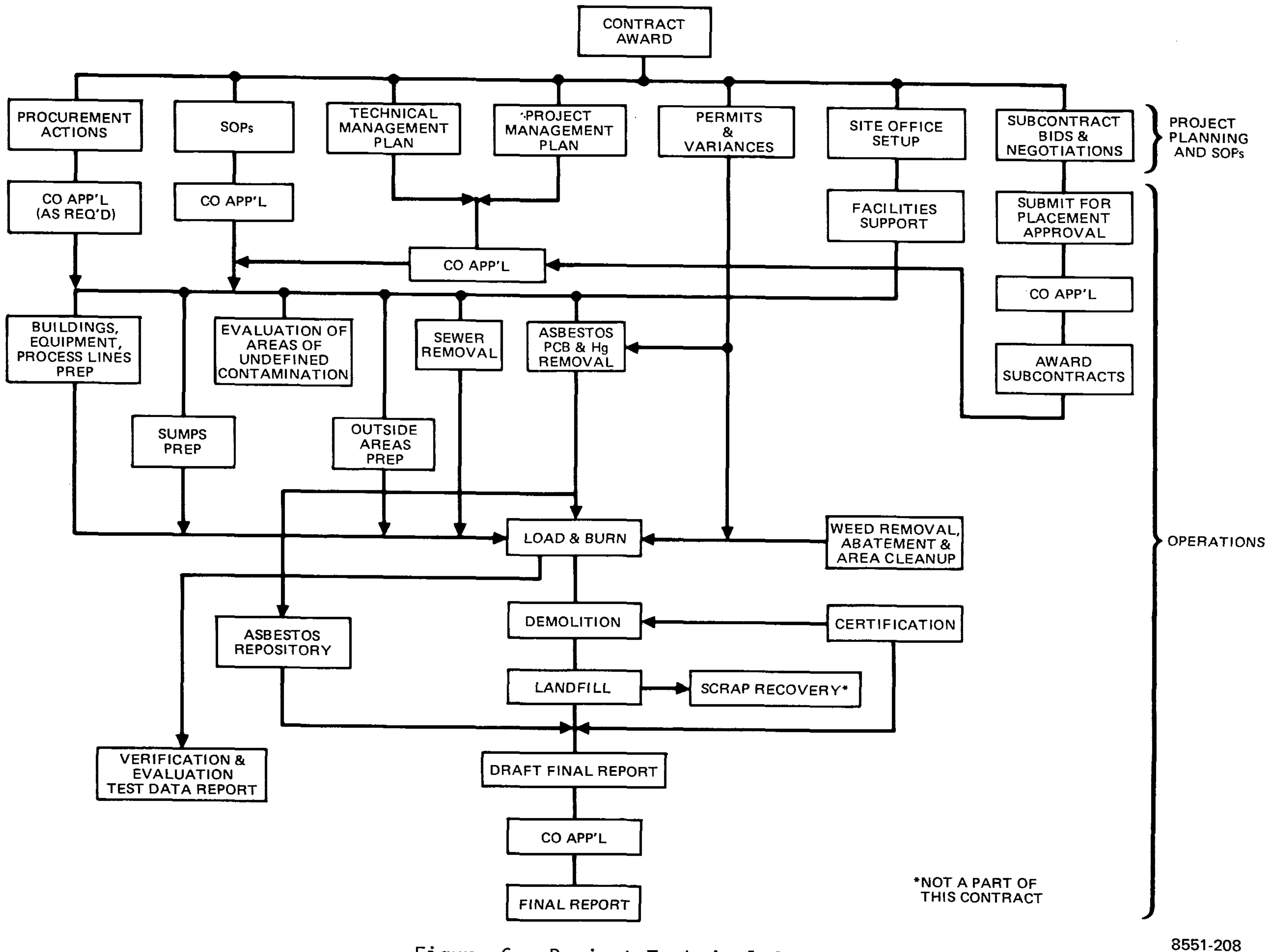


Figure 6. Project Technical Approach

detailed the overall management approach to accomplishing the project objectives and the detailed technical approach for performing the actual operations. Each document was supported by subtier documentation as shown in Figure 4.

Figure 7 details the work breakdown structure employed on the AAAP decontamination project. The work breakdown structure formed the basis for all cost and schedule controlled activities throughout the project.

3.2.2 Standing Operating Procedures

Nine SOPs were prepared and approved by USATHAMA before the decontamination operations were begun. These SOPs contained the detailed work procedures that were followed in accomplishing the decontamination activities. The nine SOPs are indicated in Figure 4.

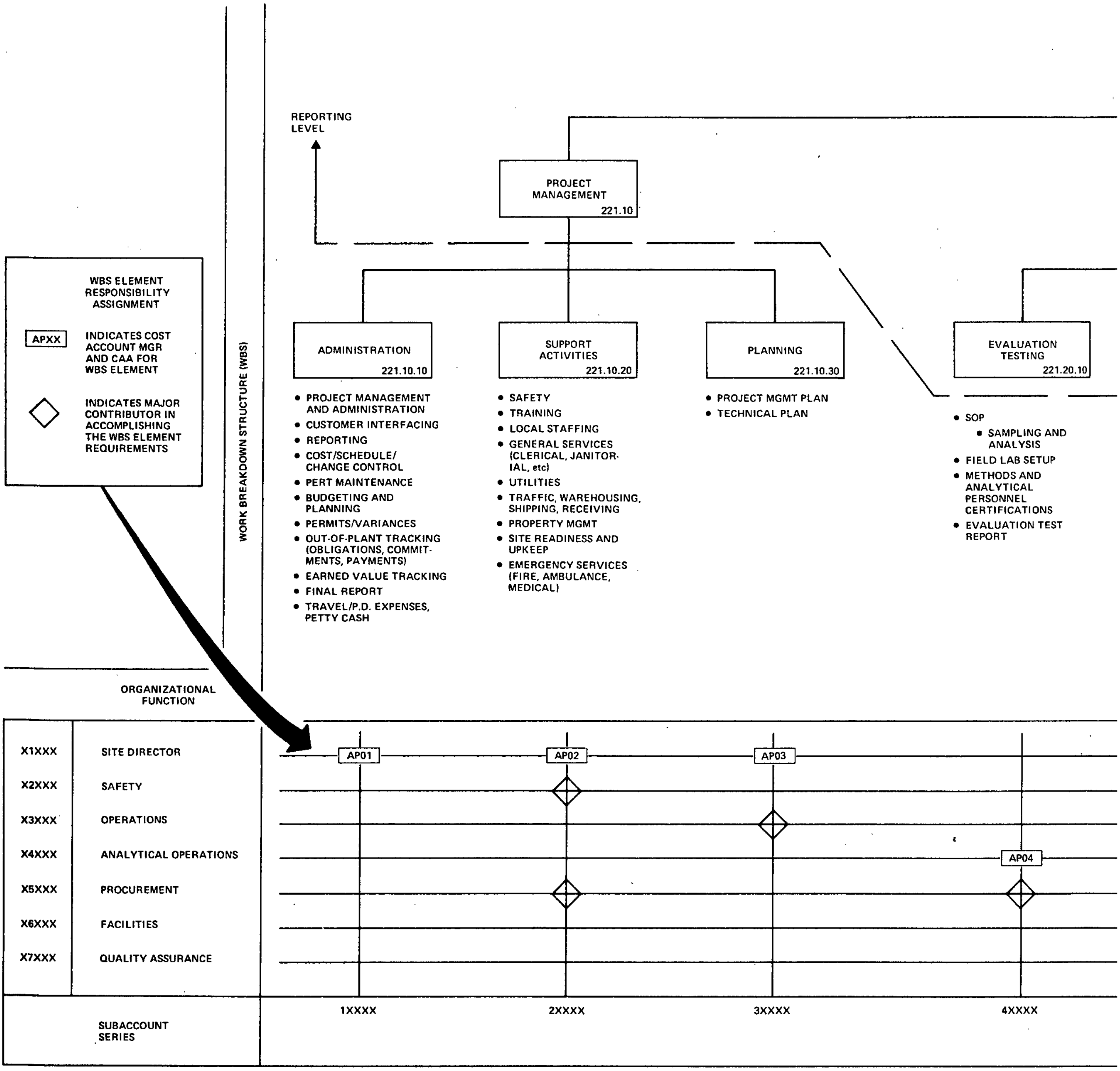
3.2.3 Permits and Variances

The Alabama Air Pollution Control Commission approved Rockwell's procedure for removing friable asbestos from the Leaseback Area and subsequent disposal of the packaged friable asbestos at an asbestos repository located on AAAP property just north of the Leaseback Area in the basement of Building 2140, which had previously been raised (see Figure 5). This concrete-lined repository provided a suitable and convenient location for the permanent disposal of the packaged friable asbestos.

EPA approval (via EPA generator number ALD980604003) to dispose of the oil switches containing PCBs and components containing mercury found in the Leaseback Area was obtained from the Region IV district office located in Atlanta, Georgia. The packaged PCB items and components containing mercury were transported offsite and disposed of by Chemical Waste Management at it's Emelle, Alabama, disposal facility.*

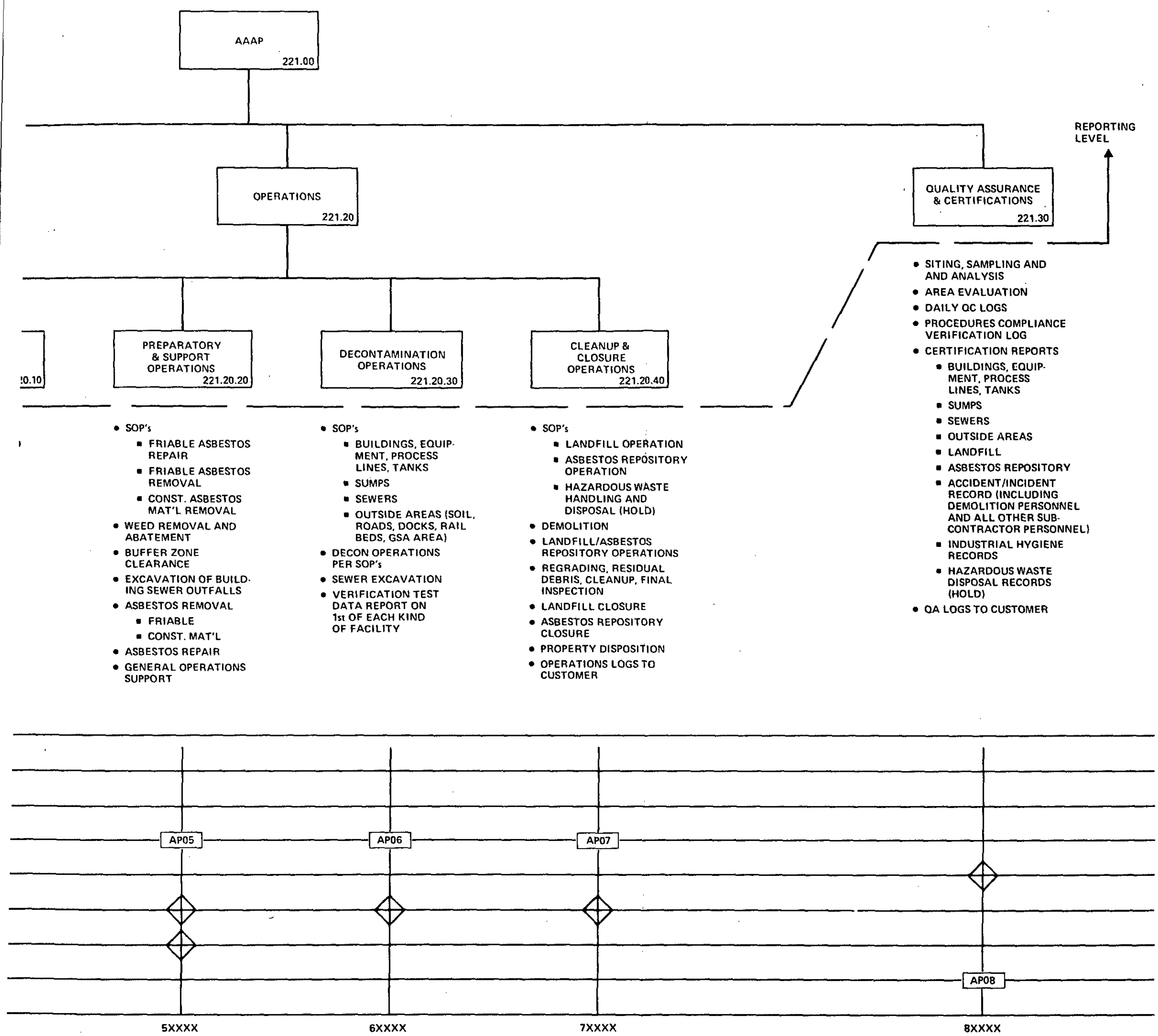
*Reference "Hazardous Waste Disposal Records," document 085TI000015 for manifest records.

AAAP WORK BREAKDOWN STRUC



1

ꞁUCTURE / FUNCTIONAL RESPONSIBILITY



2

Figure 7. AAAP Work Breakdown Structure/
Functional Responsibility

All burning operations were conducted in accordance with Proclamation 3 of the Alabama Air Pollution Control Commission. Proclamation 3 restricts open burning to the hours from 9 a.m. to 3 p.m.

No permit was required for blasting operations (floor drains were decontaminated by explosive techniques which totally shattered the floor drains, thereby incinerating any explosive residue contamination within the drains to a nonreactive condition). Likewise, no permit was required for operation of the rubble disposal area since only demolition rubble was placed in the disposal area. This was cleared with the director of the Alabama Department of Public Health, Environmental Health Administration, Division of Solid and Hazardous Waste.*

3.2.4 Sampling, Analysis, and Data Management

An extensive sampling and analysis program was implemented to 1) verify the effectiveness of the decontamination of the Leaseback Area and 2) evaluate certain buildings and areas within the Leaseback Area to confirm that these buildings/areas were, indeed, not contaminated and therefore could remain in place. The sampling and analysis was conducted in accordance with the approved SOP (0850P000010) after the onsite field laboratory (methods and personnel) had been certified for conducting the analysis. The analytical techniques employed were spot spray testing and thin layer chromotography (TLC). Both methods, along with the personnel who conducted the analysis, were certified in accordance with the USATHAMA Quality Assurance Program requirements.

*Reference "Certification of Demolition Rubble Disposal Area Management, Operations, and Closure," document 085TI000013.

Data obtained from the sampling and analysis of those structures/areas that remained in place at the conclusion of the program were entered into the USATHAMA Installation Restoration Data Management System. Data obtained to support the effectiveness of the decontamination burns were entered on hard-copy maps of each of the buildings decontaminated. These data maps are given in the certification documentation.

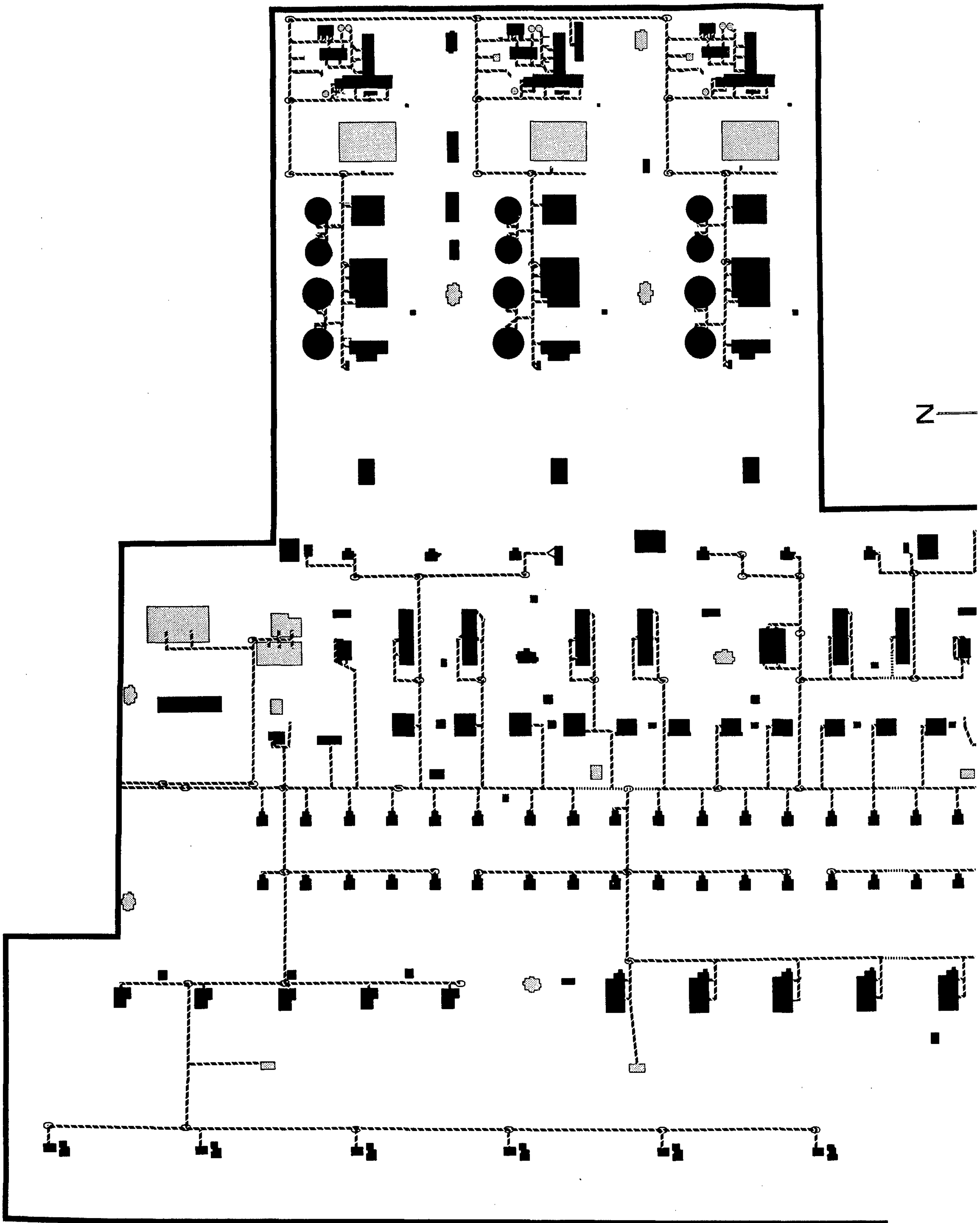
3.2.5 Evaluation Testing

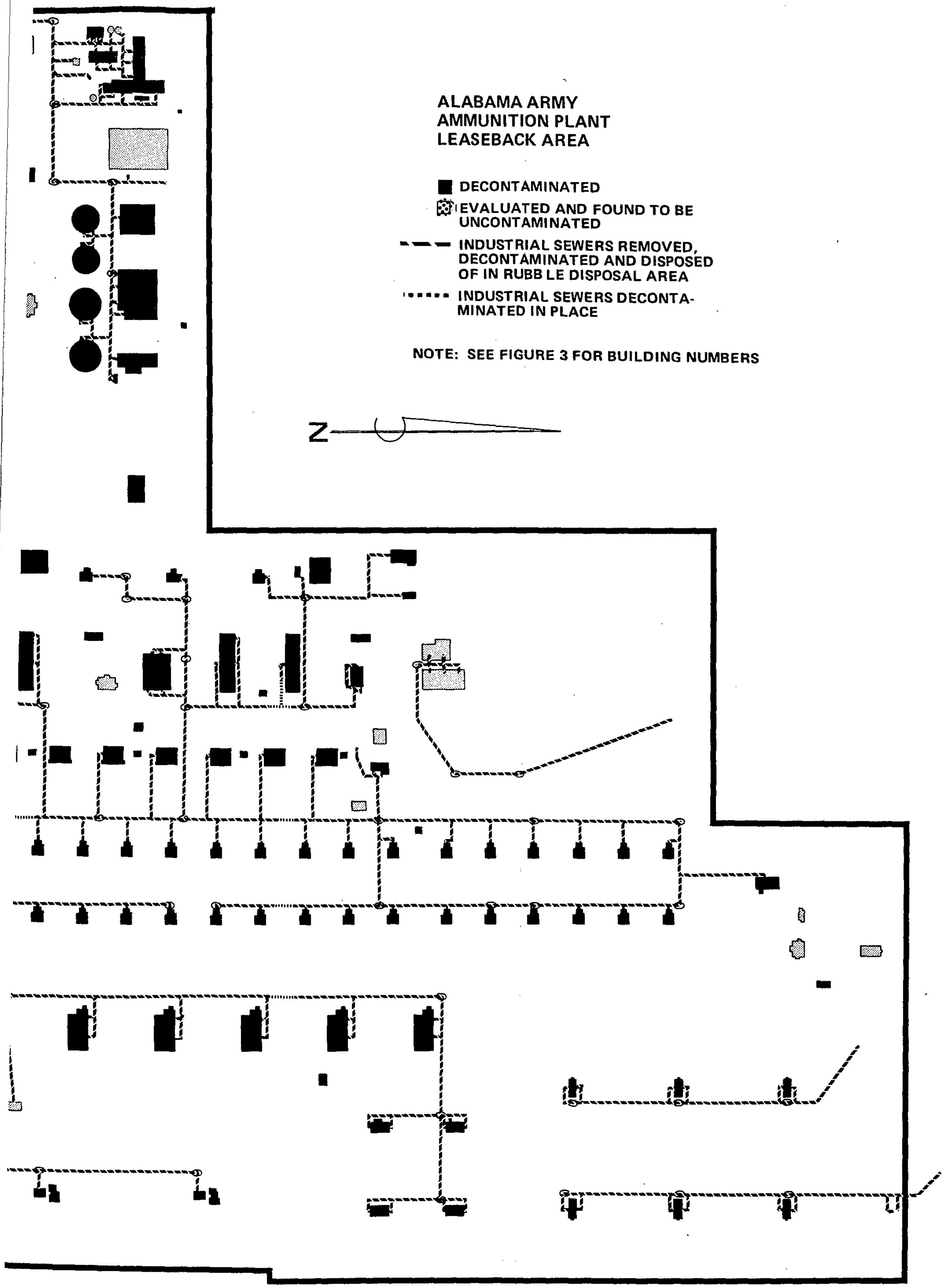
A total of 26 buildings were evaluated to confirm that they were not contaminated (Appendix A lists the buildings evaluated). In addition, an extensive soil testing program was conducted to verify the ESE survey findings relative to the contamination status of soil areas in the Leaseback Area. This program verified the ESE findings.

3.2.6 Decontamination Operations

Decontamination operations consisted of decontaminating 1) buildings (by burning), including all equipment, tanks, process lines, sumps, and basements; 2) the entire industrial sewer system (by excavating the sewer and then flaming the interior of the sewers); and 3) soil contaminated with smokeless powder grains in the 237 sewer outflow region. Prior to burning, all friable asbestos in the buildings to be decontaminated was removed, packaged, labelled, and disposed of in the AAAP onsite asbestos repository located just north of the Leaseback Area. In addition, oil switches containing PCBs and components containing mercury were removed from buildings and disposed of at Chemical Waste Management's waste disposal facility at Emelle, Alabama.

Appendix A lists the buildings decontaminated. Figure 8 shows the facilities decontaminated.





2

Figure 8. Facilities Evaluated/ Decontaminated

3.2.7 Cleanup and Closure

Following completion of decontamination operations, the buildings listed in Appendix A were demolished to the slab, and the rubble was removed and disposed of in the AAAP rubble disposal area located approximately one mile north of the Leaseback Area. Salvageable scrap metal was set aside in a large field also located just north of the Leaseback Area. Figure 9 shows the buildings that were left in place on completion of the project.

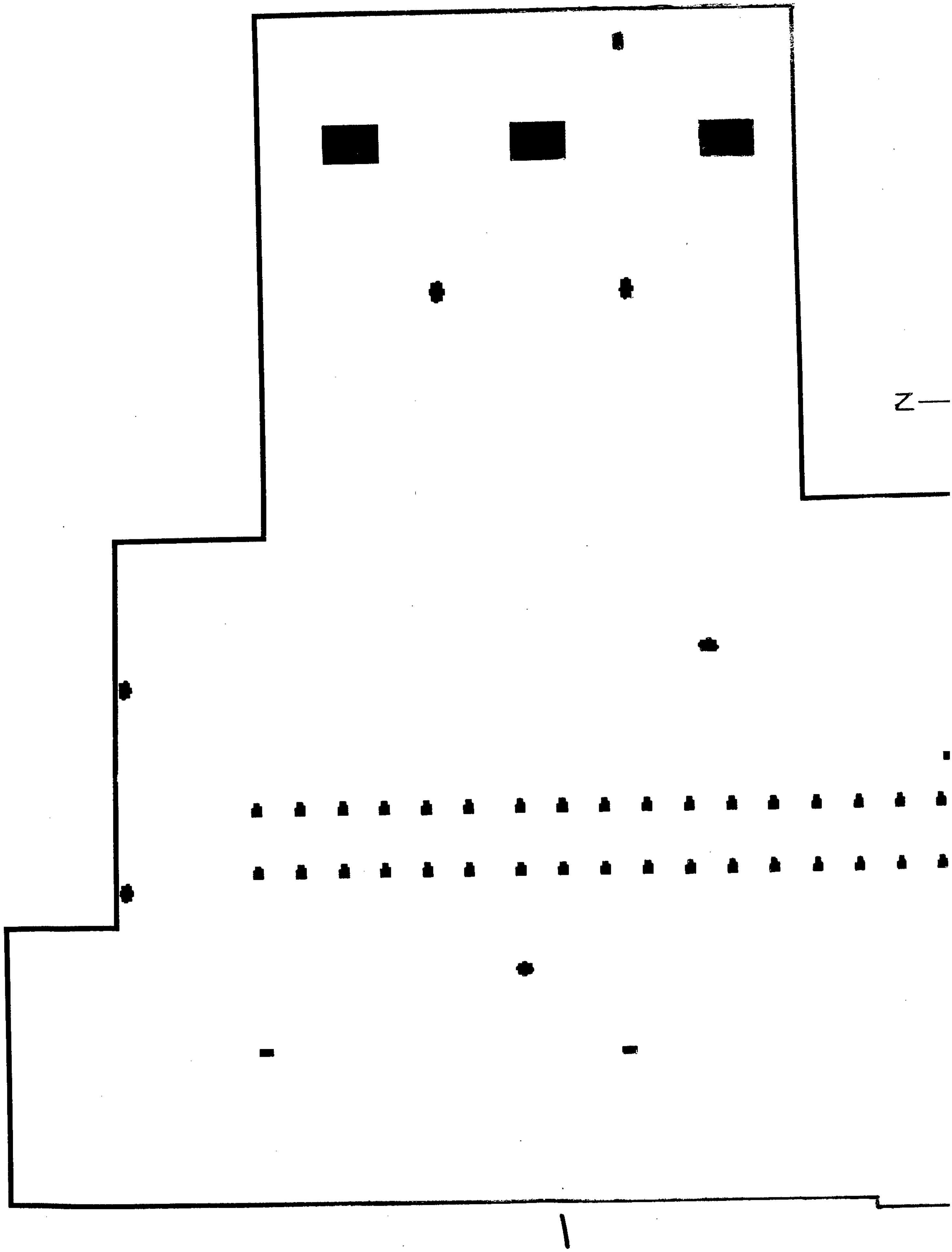
3.3 CLEANNESS (ACCEPTANCE) CRITERIA

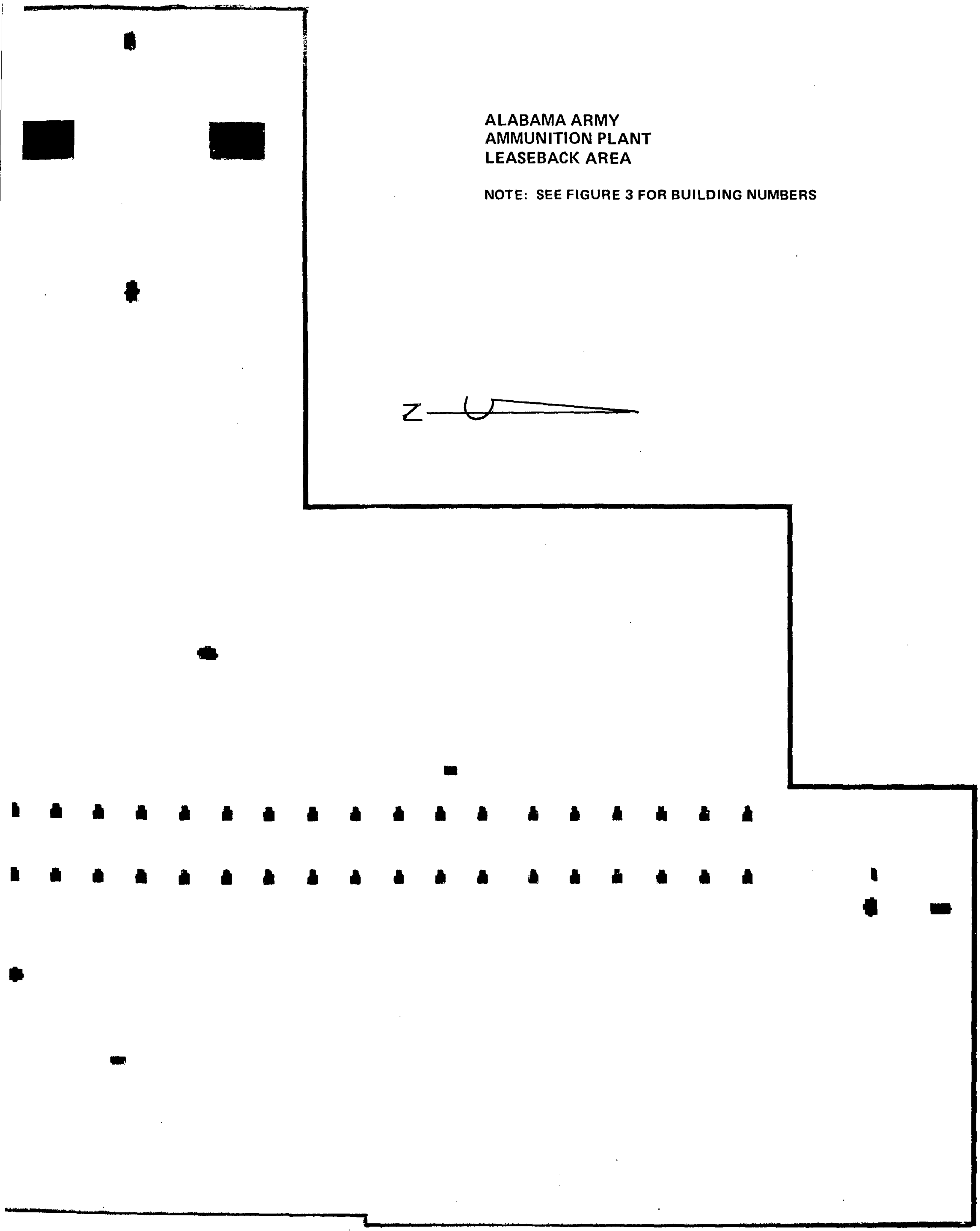
The cleanness (i.e., acceptance) criteria for the decontamination of the AAAP Leaseback Area were based on Appendix D of the contract, "Criteria upon which To Base Decontamination Procedures for Alabama Army Ammunition Plant, Leaseback Area" (included as Appendix B to this report). Based on these established criteria, the following cleanness, or acceptance, criteria were approved by USATHAMA for use on the AAAP Decontamination Project:

- Buildings, sumps, basements, savealls, process equipment/piping, tanks are acceptably clean if results from the Certipaks* prove negative (i.e., the results indicate the absence of explosives).

---

*Certipaks were developed specifically for use on this contract and consist of a specially designed packet from which it could be determined whether or not the contaminants had been destroyed and whether the required temperature had been attained. Certipaks were placed in several predetermined locations in the facility to be decontaminated and then retrieved after the burn. The predetermined locations were chosen based on judgments as to areas most difficult to heat up during the burns (e.g., floor corners in buildings, large motors, tanks, process piping, valves).





2

Figure 9. Buildings Left Standing

- Sewers are judged acceptably clean based upon applying open flame to the interior of the sewer for a minimum of three seconds. (NOTE: The 3-s process control time limit was based upon verification tests which showed that Certipaks installed in the pipes proved negative when flame of a minimum of 3-s duration was applied to the interior of the pipe).
- DNT levels in soil shall be less than 45 mg/kg.
- Soil contaminated with NC or propellant grains to a level such that it will burn* must be either burned in place or removed and burned at the flashing ground.
- Airborne friable asbestos levels must be less than those specified in 29 CFR 1910.1001, that is, no more than an 8-h time weighted average (TWA) of two fibers (greater than 5 μm in length) per cm^3 of air sampled.

3.4 QA CERTIFICATION

Certification that the AAAP Leaseback Area decontamination project has removed explosives/explosive residue hazards and industrial safety hazards from the Leaseback Area is shown in Figure 10. This certification is based on the cleanness criteria presented above and verified by over 5,000 individual pieces of data (the data are presented in the certification documentation listed in Figure 4). This certification documentation is incorporated into this final report by reference herein.

*The flammability limit for NC in soil was determined to be 125,000 mg/kg (12.5 wt. %) as determined by the EPA ignitability test (see Appendix C).

Rockwell International, Energy Systems Group, hereby certifies that decontamination of contaminated areas of the Alabama Army Ammunition Plant Leaseback Area has been completed. The decontamination was conducted in accordance with USATHAMA approved plans, Standing Operating Procedures, and contract documents.

As a result of the decontamination operations, the Leaseback Area and a small portion of the adjacent GSA area associated wtih the 237 sewer outfall region has been cleared of explosives/explosive residue hazards, friable asbestos that could present a safety hazard, and other industrial safety hazards.

Detailed data supporting the effectiveness of the decontamination are presented in the certification documentation, Part II of the final report.

A F Lillie

Anthony F. Lillie
Site Director
AAAP Decon Operations

Donald E. Empey

Donald E. Empey
Director, Quality Assurance
Energy Systems Group

Figure 10. Certification of AAAP Leaseback Area

4.0 EVALUATION TESTING AND RESULTS

4.1 SCOPE OF EVALUATION TESTING

The contract listed 65 buildings as potential candidates for evaluation as possibly uncontaminated. After a thorough review of this listing and field examination of the facilities involved, Rockwell decided to evaluate 26 of these buildings for subsequent writeoff as uncontaminated. The remaining 39 were placed in the decontamination list based on one of the following considerations:

- Cost/schedule effectiveness – many of the facilities were low worth buildings, and it was judged to be more cost/schedule effective to decontaminate and demolish the buildings than to conduct a thorough evaluation of the buildings in an attempt to write them off as uncontaminated.
- Potential for finding contamination – several of the facilities were intimately tied to either the NC or smokeless powder production process. As such, it was judged that the potential for carryover of explosives/explosive residues into these facilities was sufficiently high that it was better to decontaminate the facilities than attempt to evaluate the facilities and write them off as uncontaminated.
- Complexity of facilities – certain of the facilities were involved intimately in the NC/smokeless powder/solvent recovery operations and contained intricate and complex equipment and process piping. It was Rockwell's opinion that the time and effort necessary to fully certify these buildings as uncontaminated were not justifiable and that decontamination of such facilities was the appropriate action to be taken.

4.2 FIELD LABORATORY CERTIFICATION

Before initiating any evaluation testing activities, it was necessary to certify both the methods used in and the personnel conducting the analysis at the onsite AAAP field laboratory, which was set up at the site office. The methods and personnel certifications were performed in accordance with the requirements of the sampling and analysis SOP (see Figure 4) and the requirements of the USATHAMA Quality Assurance Program (Appendix C of the contract). Spot spray testing and TLC techniques were certified for both NC and DNT analyses on several different surfaces and in soil. When specialized analyses were required, samples were sent to Rockwell's laboratory (USATHAMA certified) at the Environmental Monitoring and Services Center (EMSC) headquarters in Newbury Park, California.

4.3 EVALUATION TESTING OF BUILDINGS

Evaluation testing was conducted on 26 buildings, as noted above. Of these, two were found to be contaminated and were subsequently decontaminated (specifically 226 A and 263 A). In the remainder of the buildings, spot spray testing was conducted of all areas most likely to contain explosive residues, such as wall corners, junctures of sill plates with slabs, tops of beams, floor drains, and the interior of any tanks and pipes contained within the building. If all results were negative, the building was written off as being uncontaminated. Of the 26 buildings evaluated, 24 were determined to be uncontaminated. Of these 24, 16 were left standing and 8 were demolished. Appendix A lists the buildings evaluated, those left standing, and those subsequently demolished.

4.4 EVALUATION TESTING OF THE 237 SEWER OUTFLOW AREA

An extensive evaluation of the 237 sewer outfall area, a region of potential soil contamination as identified in the contract, was conducted. Based on the criteria presented in Appendices B and C of this report, the only contamination was the propellant grains, which were removed and burned.

4.5 EVALUATION TESTING OF OUTSIDE AREAS

Thirty-five samples were taken from areas near the entrances and exits of buildings where NC/smokeless powder propellant materials had been handled and along railbeds where the material had been transported. Of these, 17 indicated positive TLC readings for DNT. Quantitive analysis using gas chromotography techniques indicated that the DNT levels in the soil were below the 45 mg/kg cleanness criteria (Appendix B).

4.6 RESULTS OF THE EVALUATION TESTING PROGRAM

Twenty-six buildings were evaluated in an attempt to write them off as uncontaminated. Of the 24 buildings found to be uncontaminated, 16 were left standing and 8 were demolished and the salvageable scrap from the buildings delivered to the salvageable scrap set-aside area (see Figure 5) just north of the Leaseback Area.

An extensive evaluation testing program for soil contamination in the 237 sewer outflow area was conducted. The level of NC was below the cleanness criteria (see Apendices B and C), and the only decontamination that was required was the removal and burning of the smokeless powder propellant grains found in this region. A total of 35 soil samples were taken to determine DNT contamination at the entrances and exits of buildings and along railroad beds where transport between buildings occurred. Of these, 17 indicated positive TLC readings, but quantitative analysis by gas chromotography methods at Rockwell's EMSC headquarters indicated that the DNT levels were below the 45 mg/kg cleanness criteria for DNT in soil. This confirmed the findings from the ESE environmental survey conducted in the AAAP Leaseback Area.

5.0 DECONTAMINATION OPERATIONS AND RESULTS

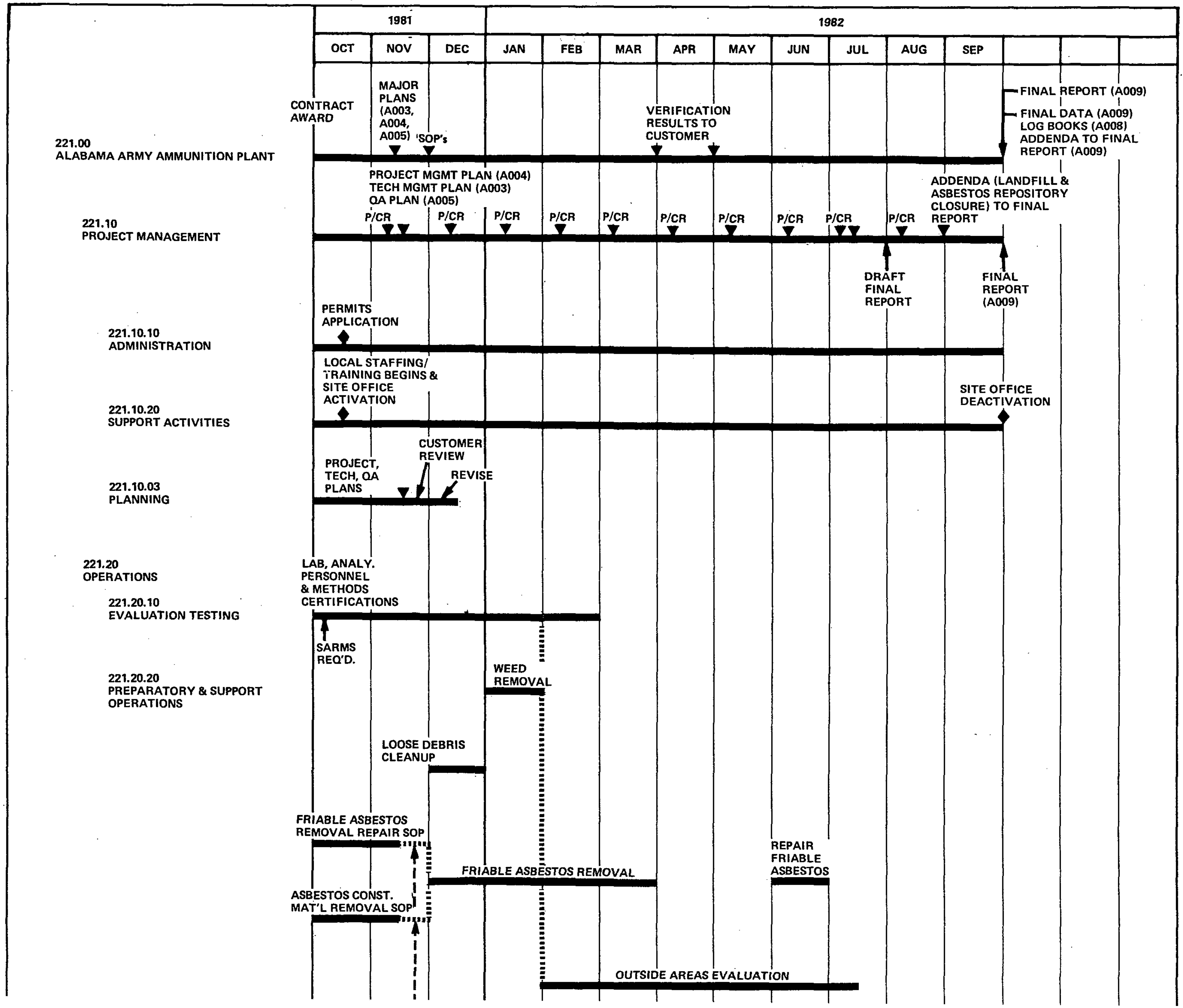
5.1 SCOPE OF DECONTAMINATION OPERATIONS

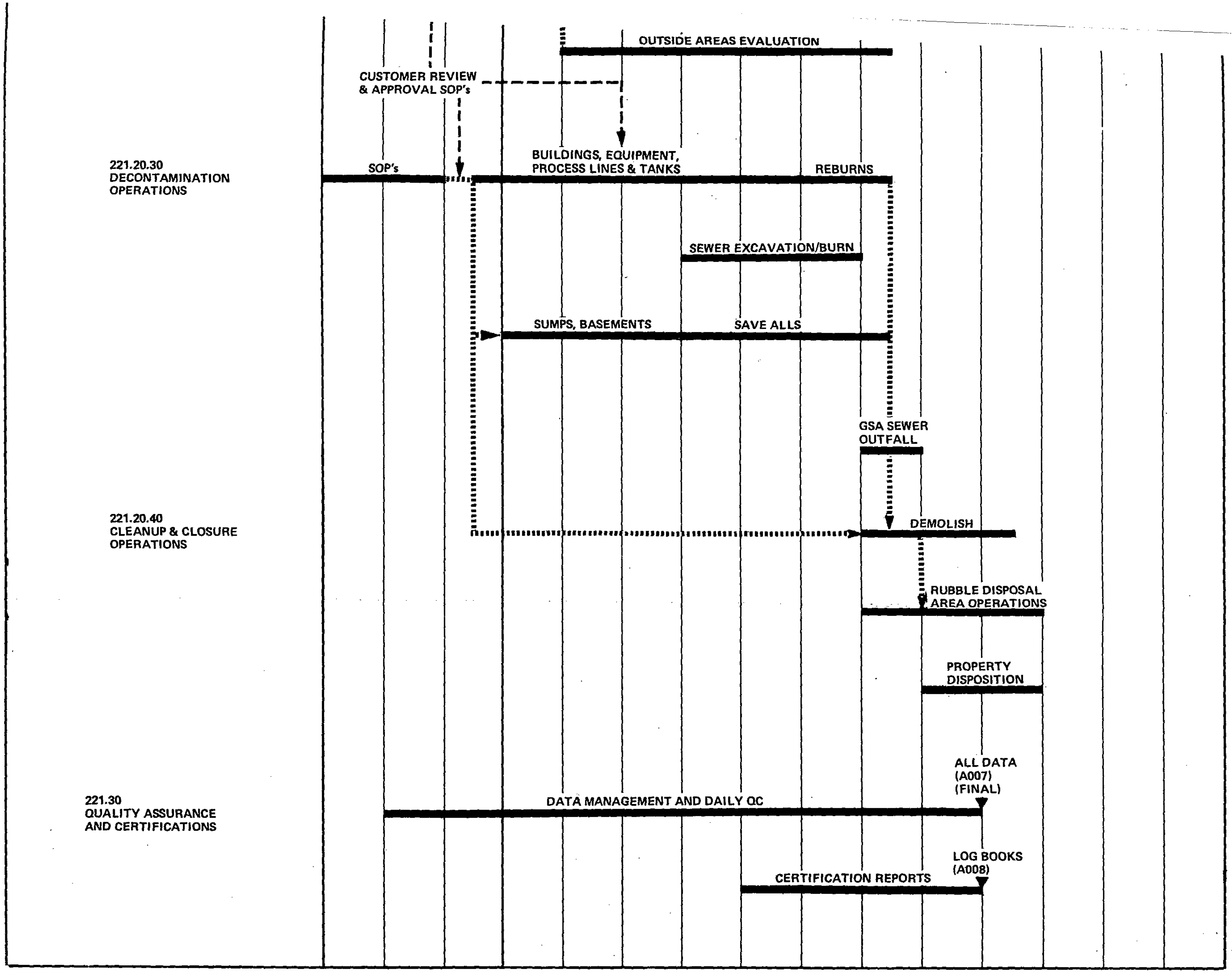
The contract scope of the decontamination operations required decontaminating 142 buildings, 47,000 ft of industrial sewer system located in the Leaseback Area, and all sumps, basements, equipment, tanks, and process lines in the contaminated buildings; burning propellant grains in the 237 sewer outflow region; and evaluating and subsequently decontaminating areas found to be contaminated but not listed in the contract.

As noted in Section 3.2.5, Rockwell elected to decontaminate more buildings than were required by the contract. In all, a total of 193 buildings were decontaminated. Approximately 47,000 ft of the industrial sewer system, including sewer system laterals to all buildings, was removed and decontaminated. Underground process piping in the 100 area (the NC production area) was excavated and decontaminated. The 237 sewer outflow area was decontaminated of visible smokeless power propellant grains found in the area. A total of 407 tanks and 445 sumps were decontaminated during the project. Before starting decontamination operations, 21,000 ft^3 of friable asbestos was removed from buildings to be decontaminated, and loose friable asbestos existing in the outside areas in the Leaseback Area was removed and disposed of. Electrical switches containing PCBs and components containing mercury found in the area were removed and disposed of in accordance with EPA and State of Alabama regulations governing the disposal of these substances.

The project schedule for decontamination is shown in Figure 11. Briefly, decontamination operations began with the removal of friable asbestos in mid-December 1981 and closed with the last of the decontamination burns at the end of July 1982. The demoliton of buildings that had been decontaminated and the disposal of the demolition rubble along with the recovery of salvageable scrap metal were accomplished by the end of September 1982.

PROJECT SCHEDULE





2

Figure 11. Project Schedule

5.2 PREPARATIONS

Before decontamination operations (e.g., burning) could begin, it was necessary to remove all friable asbestos from the buildings to be decontaminated. Figures 12 and 13 show friable asbestos removal operations in progress. After being thoroughly wetted, the friable asbestos was removed and placed in plastic bags marked with appropriate warning labels. The bags were then tightly sealed and delivered to the asbestos repository for permanent disposal (see Figure 14).

All friable asbestos was handled in accordance with 29 CFR 1910 requirements, and disposal of the friable asbestos was conducted in accordance with the provisions of 40 CFR 61.25. A total of 46 personnel airborne asbestos samples were obtained during the removal of the $\sim$21,000 ft^3 of friable asbestos. The maximum exposure indicated by analysis of these samples was an 8-h time weighted average (TWA) of 1.2 fibers greater than 5 μm in length per cm^3 of air sampled. This is well below the OSHA permissable exposure limit (PEL) of 2.0 fibers greater than 5 μm in length based on an 8-h TWA. After all friable asbestos had been disposed of, the repository was sealed with a 4-in. concrete cap pad, and appropriate warning signs were permanently installed (see Figure 15).

While preparing the buildings for decontamination, Rockwell found several oil-insulated electrical switches that contained PCBs in excess of 50 ppm (levels of PCBs in the oil were of the order of 100 to 500 ppm). With one exception, these switches were all found in the 100 area (that is, the NC production area) buildings. In addition, several hundred components containing mercury, such as thermometers, mercury switches, and instrumentation relays, were also found.

Change proposals were submitted by Rockwell to USATHAMA for removal and disposal of these items in accordance with procedures delineated in the change proposal. USATHAMA approved these change proposals, and the items containing

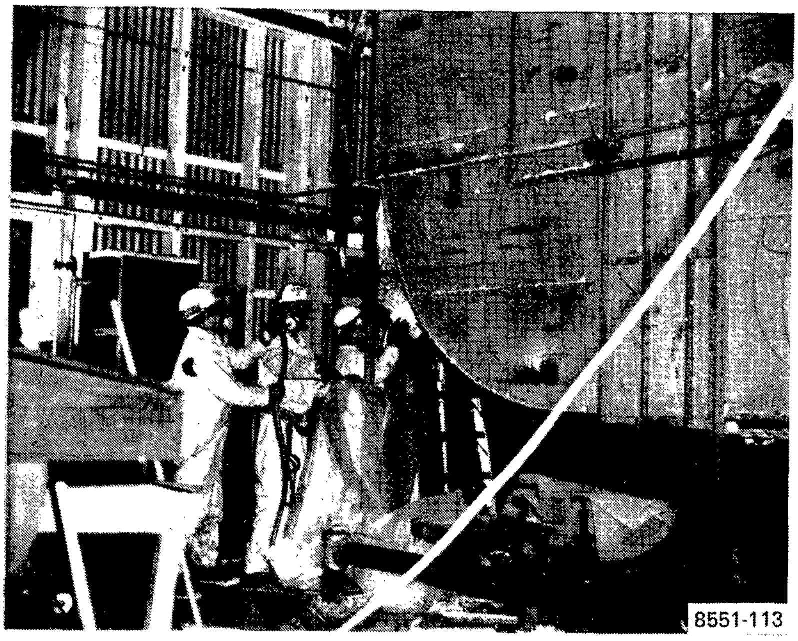


Figure 12. Asbestos Removal Operations

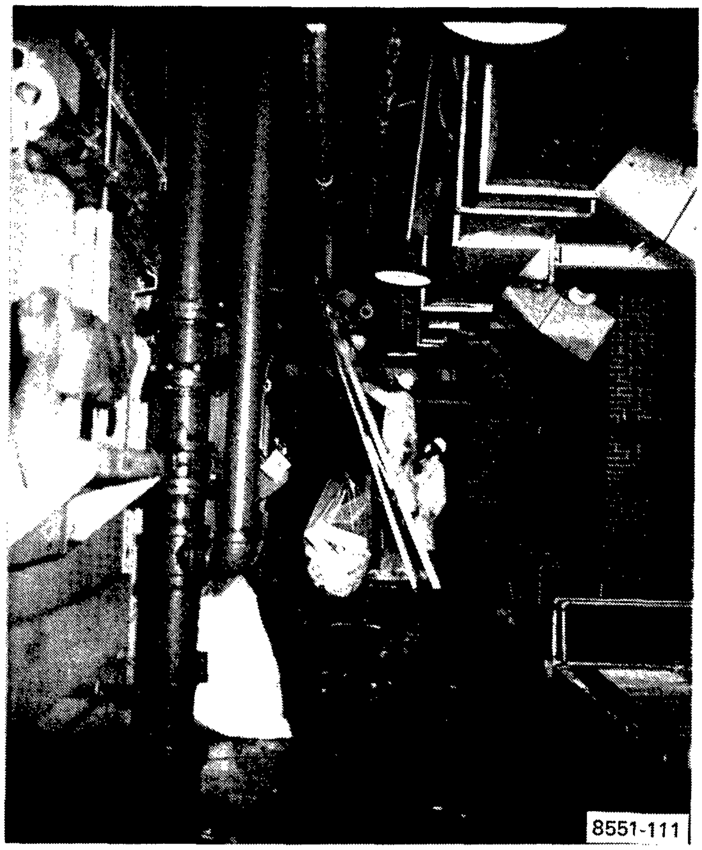


Figure 13. More Asbestos Removal Operations

Figure 14. Disposal of Friable Asbestos in Concrete Basement of Building 214D

Figure 15. Sealed Asbestos Repository (white sections are the concrete cap)

PCBs and mercury were removed and disposed of (under EPA generator number ALD980604003) at Chemical Waste Management's waste disposal facility at Emelle, Alabama. All removal and disposal operations were conducted in accordance with applicable federal and State of Alabama hazardous waste management regulations.

5.3 VERIFICATION TESTING

Verification tests were performed on each type of building in the AAAP Leaseback Area. After the Certipaks that had been installed in the buildings prior to the burn were evaluated, the data were assembled and analyzed, and a report was prepared and sent to the USATHAMA contracting officer's representative (COR). After COR verbal approval, the remaining types of buildings covered by the verification test were decontaminated. Figures 16 and 17 show a verification test form and verification test data typical of what was submitted to the COR as confirmation of the verification test.

5.4 DECONTAMINATION OF BUILDINGS

After the removal of the friable asbestos, electrical oil switches containing PCBs, and components containing mercury (as applicable), the buildings were prepared for decontamination by burning. Preparations included loading straw and wood dunnage into the buildings and spraying the dunnage with diesel fuel. The burn was started using lighted road flares.* Figure 18 shows various building burns in progress.† Figure 19 is a good illustration of the intensity of the burns. Note in these photographs how the piping and structural steel have been warped and bent by the intense heat of the burns.

---

*In a few instances, it was judged advisable (from a safety standpoint) to ignite the dunnage/diesel fuel combination from a distance (>500 ft). This was accomplished using specially prepared, electrically fired, igniters placed in the building(s).

†Original prints at USATHAMA, Aberdeen Proving Ground, Maryland.

AAAP Decon Operations
Verification Test Result
Contract DAAK11-81-C-0094
CDRL Item A006

On 06-09-82, a decontamination verification test was conducted on the following structure(s) in building 105A :

		Number
☒	building	1
☒	sump(s) or pit	2
☒	drain(s)	20
☒	process pipe(s)	√
☒	tanks(s)	√
☒	equipment	√

The decontamination verification test was conducted in accordance with the applicable SOP(s) and results were as follows:

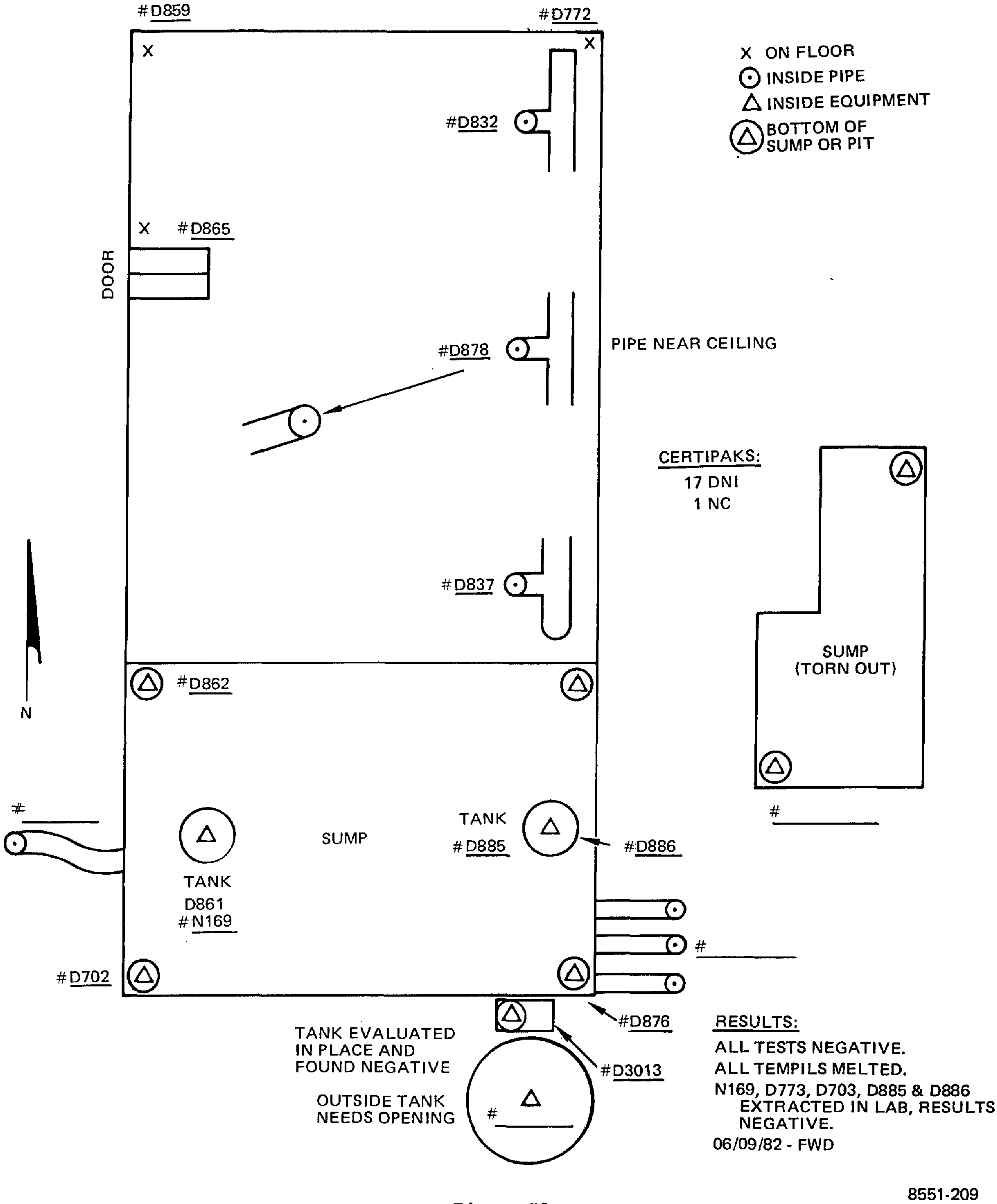
All Certipak(s) negative
Drain(s) shattered

This certifies that the decon test was successful. In accordance with USATHAMA verbal approval of 06-18-82 decon operations on remaining facilities of the 105 type will proceed.

A F Lillie
A. F. Lillie, Site Director

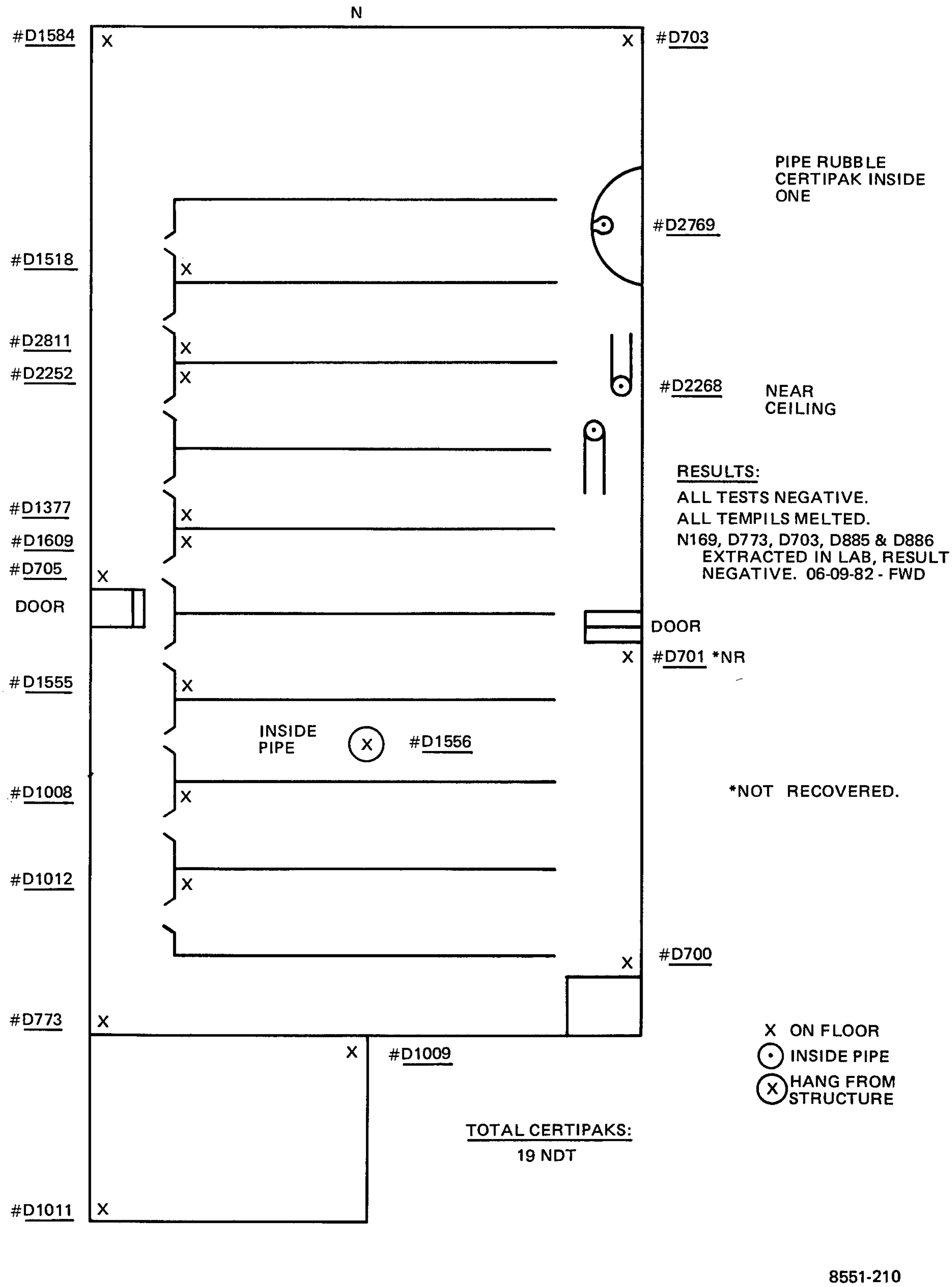
D E Owens
D. E. Owens, Rockwell, QA

Figure 16. Typical Verification Test Form



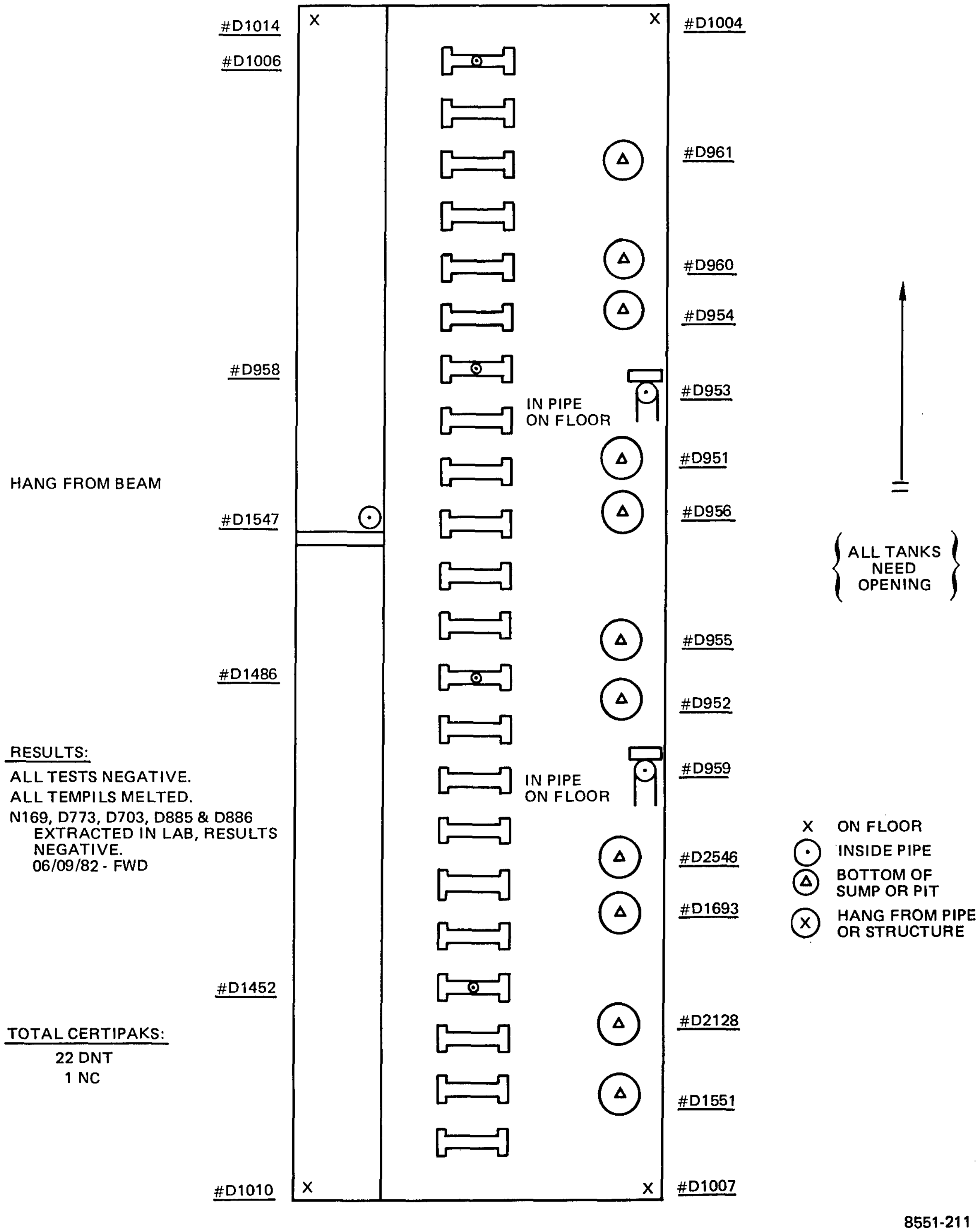
a. First Floor

Figure 17. Typical Verification Test Data (Building 105A)



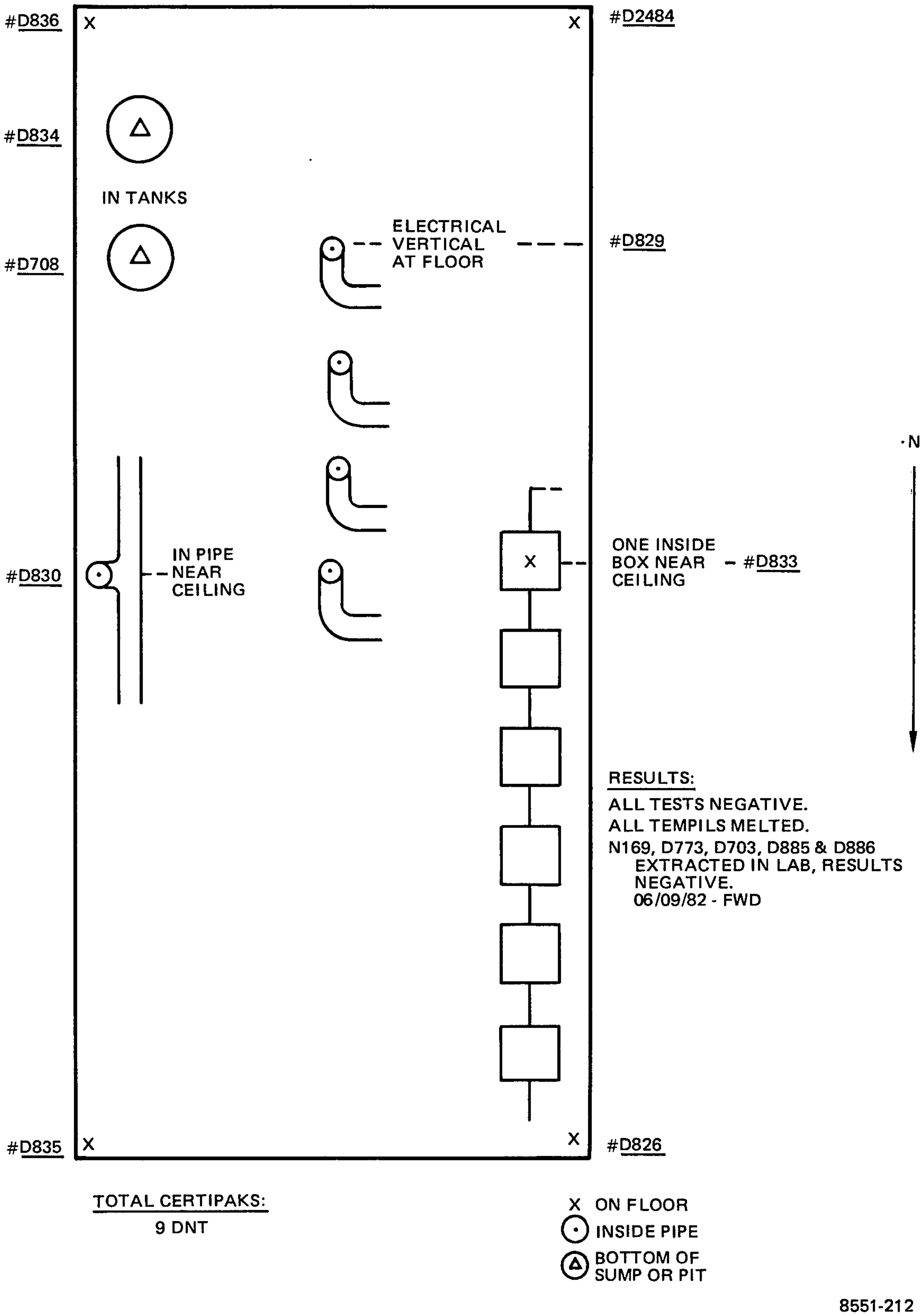
b. Second Floor

Figure 17. Typical Verification Test Data (Building 105A)



c. Third Floor

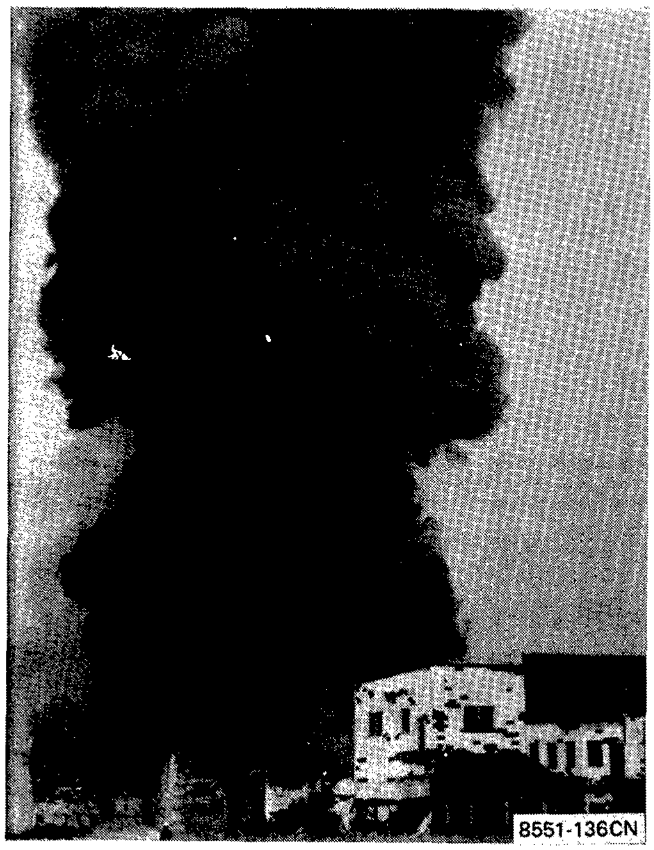
Figure 17. Typical Verification Test Data (Building 105A)



d. Fourth Floor

Figure 17. Typical Verification Test Data (Building 105A)

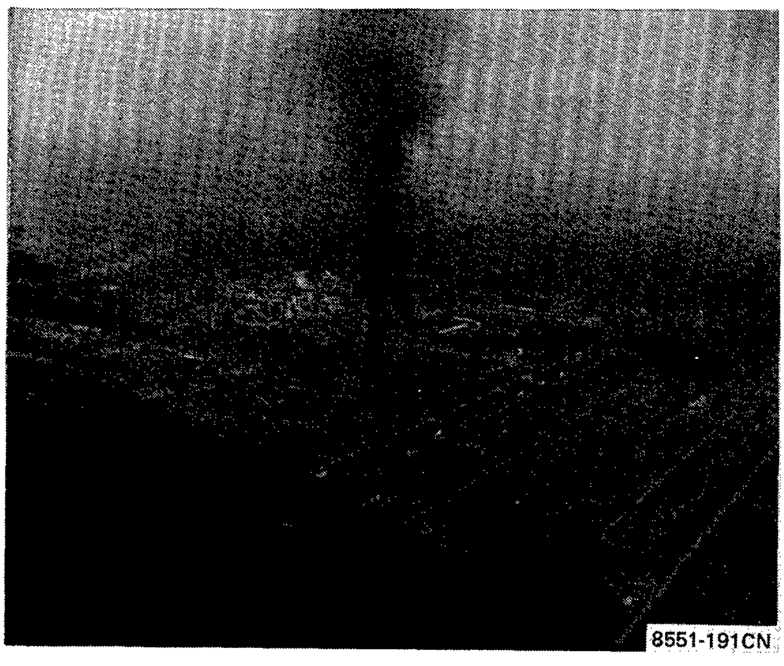
a. Building 109A



b. Building 112A

Figure 18. Typical Building Decontamination Burns

c. Buildings 111A and 113A



d. Completion of Decontamination Burn of 109C, 111C, 112C, and 113C

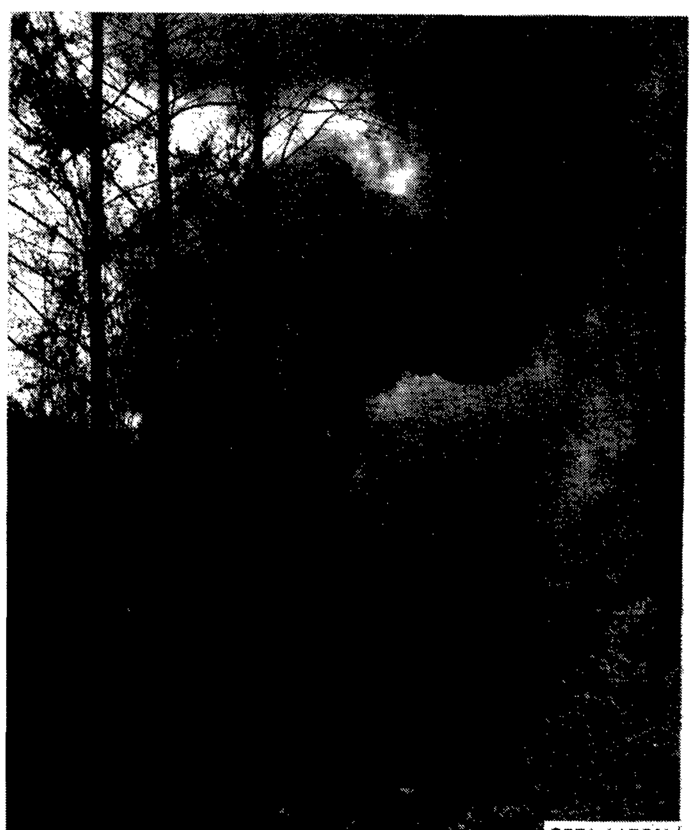
Figure 18. Typical Building Decontamination Burns

e. Burning Building 208E (the water stream is being used to prevent the fire from spreading to surrounding vegetation)

f. Building 219A

Figure 18. Typical Building Decontamination Burns

g. Buildings 214 B7 and 214 B15

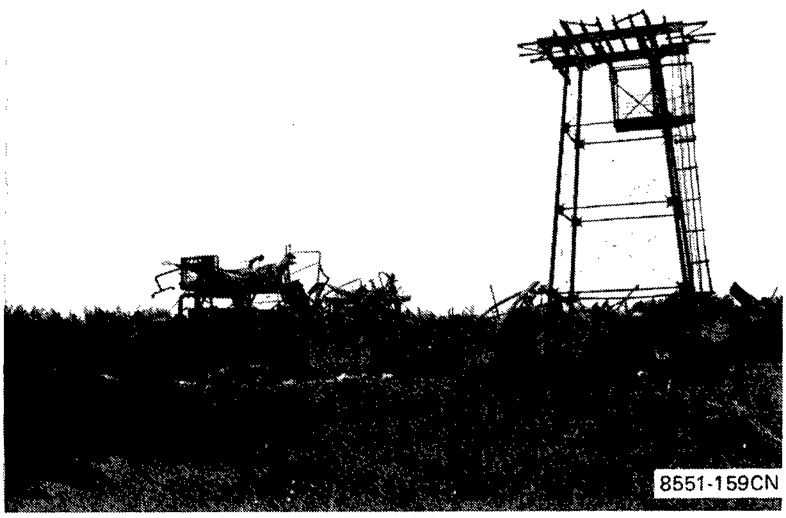


h. Building 237F

Figure 18. Typical Building Decontamination Burns

a. Building 202G

b. Building 112B



c. Building 109B

Figure 19. Aftermath of the Burns

Based on the Certipak data, observation of the burns, and viewing of the spalled concrete and wreckage after the burns, the buildings and all contained process piping, equipment, tanks, and other items within the buildings were deemed thoroughly decontaminated. In a few rare instances, the Certipaks had melted and could not be retrieved.

5.5 SEWER DECONTAMINATION

Approximately 47,000 ft of the industrial sewer system in the Leaseback Area, including mainlines, interceptor lines, and building laterals, was excavated* and decontaminated using hand-held flamer rigs. Figure 20 shows sewer decontamination operations underway. Approximately 200 ft of sewer were flamed in place. These sections of sewer consisted of four sections running under the so-called Kimberly Clark "superhighway," one section located in the southern reaches of the 214 area, and two short sections in the 100 area.

Approximately 2,500 yd^3 of concrete-encased sewer was removed (see Figure 20). Approximately 40% of the lineal footage removed was encased in concrete.

The decontaminated sewer sections were hauled to the rubble disposal site by the demolition contractor for final disposal.

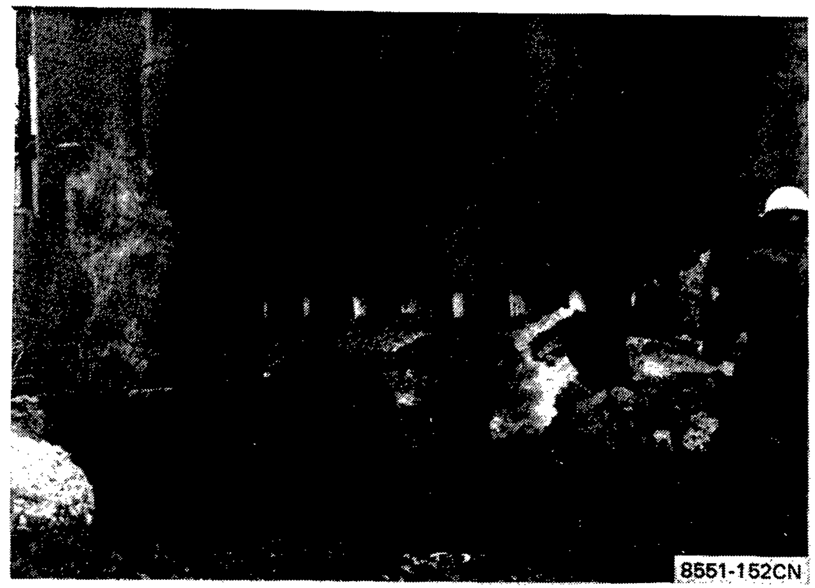
5.6 DECONTAMINATION OF FLOOR DRAINS, SUMPS, BASEMENTS, AND SAVEALLS

Floor drains within the buildings were decontaminated using explosive techniques. Four hundred grain per foot detonating cord was pulled through the floor drains from the outfall of the drain within the building. For drain line diameters greater than 4 in., 800-gr/ft cord (a double strand of

*Excavation was performed by Wrecking Corp of America, St. Louis, Inc., Alexandria, Virginia, under subcontract to Rockwell.

a. Excavating Sewer Lines
(Excavation kept wet while digging)

b. Flaming a Sewer Section (Note flame at exit of section)



c. Flaming a Sewer Section (Note flame at exit of section

Figure 20. Sewer Excavation/Decontamination

400-gr/ft cord) was used. The explosive techniques incinerated any residues in the drain to a nonreactive condition. Figure 21 shows a typical result of a floor drain detonation. The photograph shows a 6-in.-thick floor slab fractured by the force of the detonation in the underground floor drain.

Figure 21. Evidence of Floor Drain Decontamination

Decontamination of subsurface sumps, basements, and the tanks required a supply of compressed air during the burn in order to initiate and maintain the combustion process. The sumps/basements/tanks were loaded with dunnage, which generally consisted of a mixture of wood and charcoal briquets doused with diesel fuel. A compressed air line was installed into the bed of the structure, and then the dunnage was ignited using lighted road flares. This process produced intense heat within the structure, causing the concrete to spall and, in many cases, the Certipaks, which had been installed to verify the effectiveness of the decontamination, to melt. In total, 445 sumps were decontaminated during the project.

5.7 PROPELLANT GRAIN DECONTAMINATION

As noted in Section 4, propellant grain contamination was found in the 237 sewer outflow area and consisted of mounds of smokeless powder propellant grains. Figure 22 illustrates the source of these grains, which had been flushed through the industrial sewer system in the 237 area during production operations. The grains, some of which are visible in Figure 22, were excavated and placed into nearby buildings during building decontamination.

5.8 DEMOLITION/SALVAGEABLE SCRAP REMOVAL

Of the 193 buildings that had been decontaminated, 145 were demolished to the slab* and the rubble hauled off to the onsite rubble disposal site† located just north of the Leaseback Area on AAAP property (see Figures 5 and 23). Figure 24 illustrates demolition activities in progress.

Salvageable metal scrap, such as tanks, pumps, equipment, process lines, and structural steel, that was readily retrievable was hauled to the salvageable scrap storage area located just north of the Leaseback Area (see Figure 5). Figure 25 shows the salvageable scrap storage area.

5.9 FINAL CLEANUP AND INSPECTION

After completion of the demolition and salvageable scrap removal operations, the entire Leaseback Area was disked and final cleanup completed. A walk-through of the area was conducted by both Rockwell and USATHAMA representatives for final clearance and acceptance of the area. Figure 26 shows the Leaseback Area after completion of final cleanup activities.

---

*The 193 buildings included the 214 series type buildings which were left standing.

†Demolition, rubble cleanup/removal, and salvageable scrap storage were performed by Asphalt Products, Inc., Childersburg, Alabama, under subcontract to Rockwell.

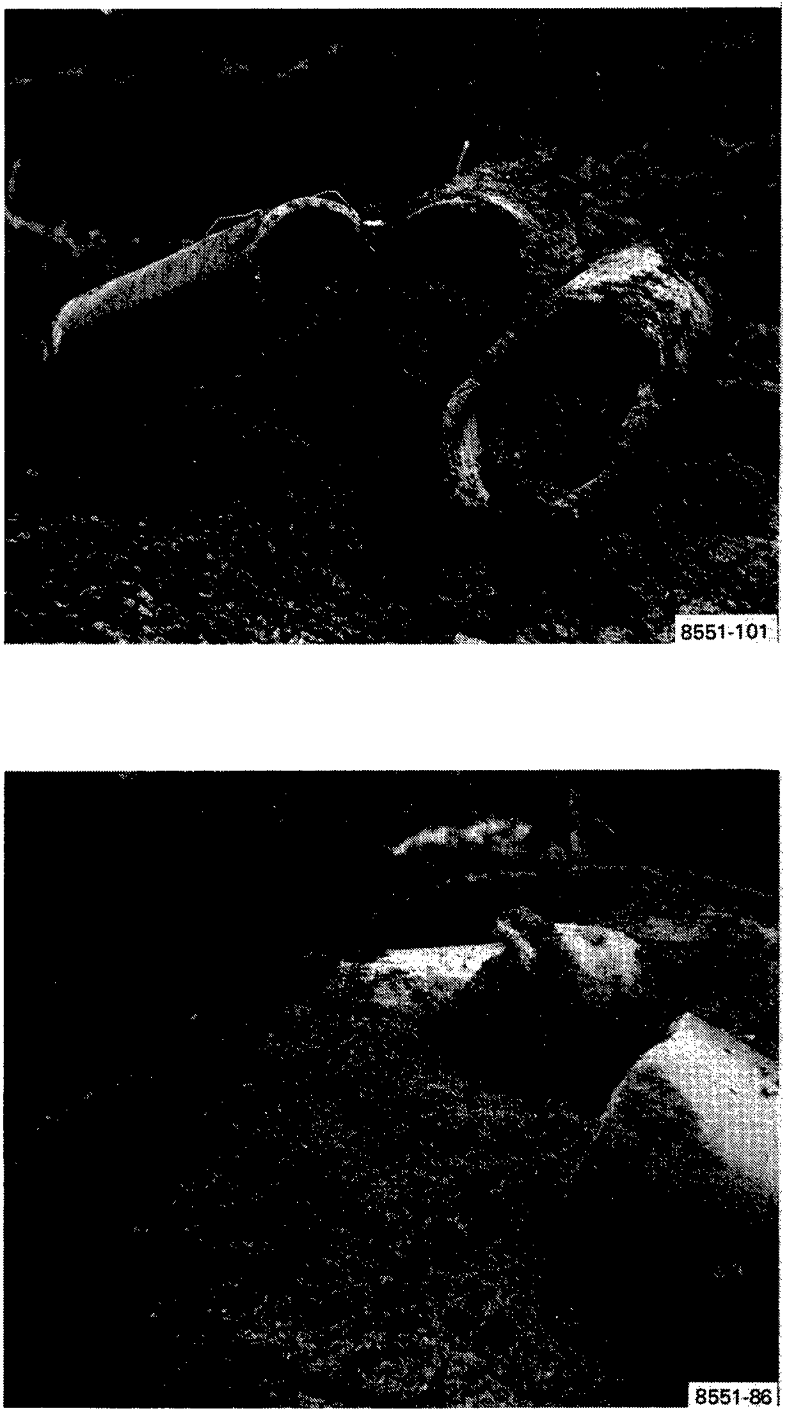


Figure 22. Smokeless Powder Propellant Grains in the 237 Sewer Outflow Region

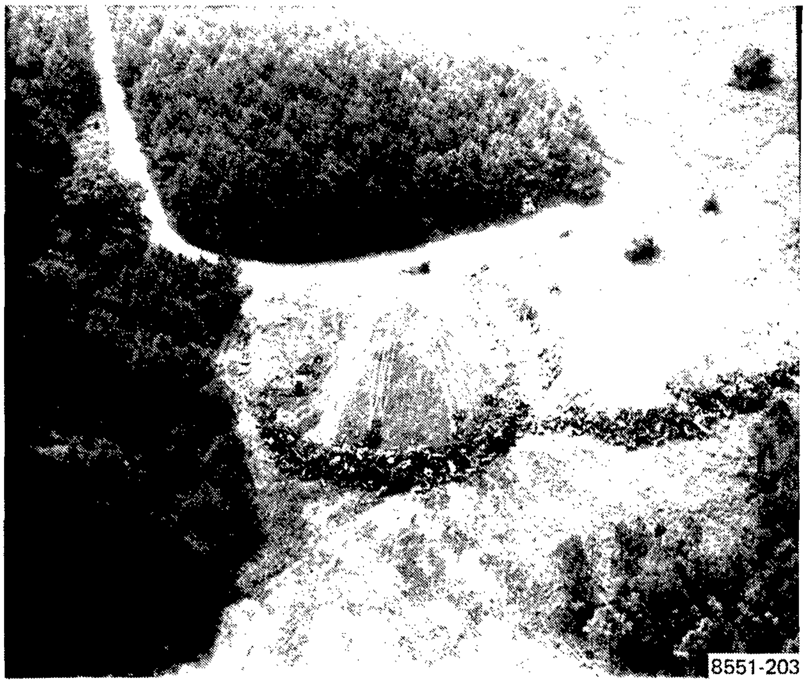


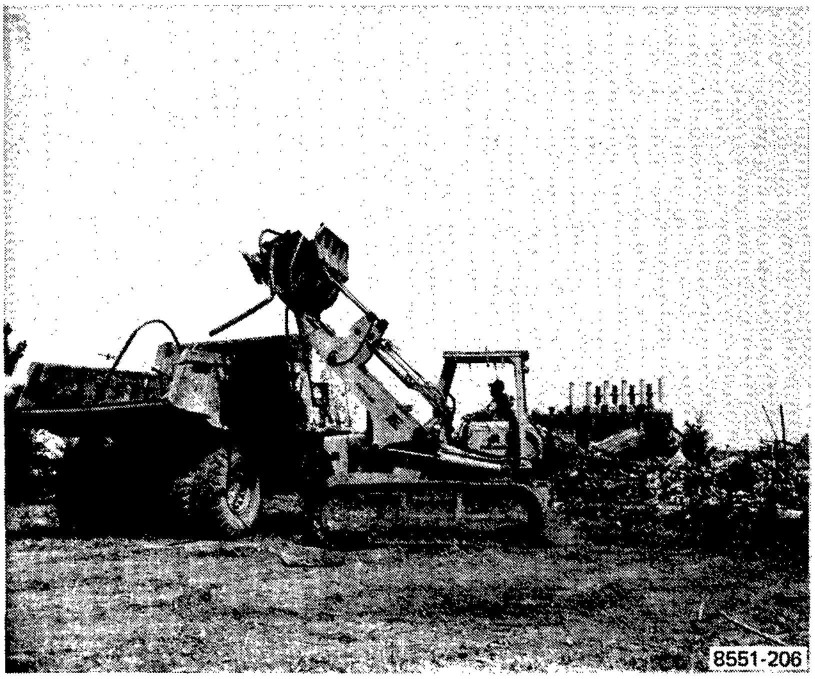
Figure 23. Rubble Disposal Site

5.10 DECONTAMINATION RESULTS

Based on Certipak data taken during the decontamination burns, tł effectiveness of the decontamination has been verified. All Certipaks negative. In some instances, reburns of certain areas were necessary achieve this result.

The entire industrial sewer system (with the exception of four sho ments under the KC superhighway, one segment located in the southern en the 214 line, and two short sections in the 100 area) was excavated, dє inated, and hauled off to the rubble disposal site. The sections left place were decontaminated before final backfilling.

The propellant grains in the 237 sewer outflow region were exhur burned in place.



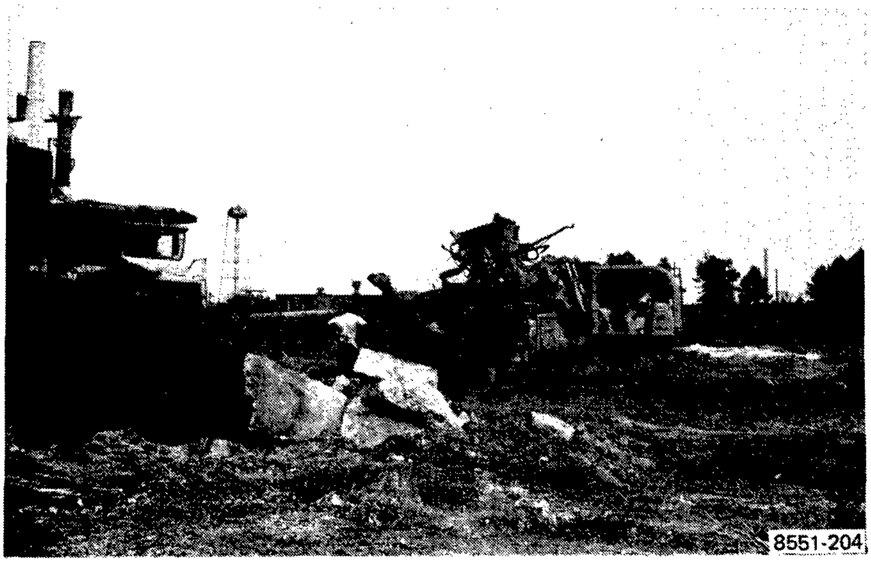


Figure 24. Demolition in Progress

Figure 25. Salvageable Scrap Storage Area

Figure 26. AAAP Leaseback Area After Final Cleanup

The friable asbestos repository was sealed with a 4-in.-thick concrete slab, and the required warning signs were permanently installed.

All electrical oil switches containing PCBs and components containing mercury found within the Leaseback Area were removed, packaged, and transported offsite to an approved waste disposal facility where final disposal occurred (Emelle, Alabama, under EPA generator number ALD980604003).

All buildings that remain on the Leaseback Area with friable asbestos (which was repaired wherever open-to-the-atmosphere asbestos was found) were monitored for airborne asbestos particles. All samples taken indicated levels below the 29 CFR 1910.1001 acceptance levels.

6.0 QA CERTIFICATIONS

6.1 SCOPE OF CERTIFICATION

The scope of certification is clearly defined within the contract as follows:

- Section C.3.2.4.6 states that Rockwell shall conduct certification testing of all buildings, structures, equipment, tanks, sumps, sewers, floor drains, process lines, basements, loading docks, railbeds, roads, soil areas, etc., which were decontaminated to ensure that the decontamination is complete. Test results shall be entered into the data base and documentation which certifies the entire Leaseback Area and that portion of the 237 series sewer area located in the GSA area are cleared of explosives, explosive residues, asbestos, and other industrial safety hazards. Similar documentation shall certify the landfill sites have been properly managed and closed.
- Section C.3.1.6 states that Rockwell shall perform decontamination of all contaminated areas in accordance with the detailed operations plans, SOPs, and criteria for decontamination (Appendix D of the contract) and ARRCOM regulation number 385-5* and TB700-4† (Appendix E of the contract). Certification shall be submitted that decontamination has been accomplished.

The scope of the certifications therefore includes certification 1) that decontamination of contaminated areas has been completed; 2) that the decontamination was conducted in accordance with approved plans, SOPs, and contract

*ARRCOM Regulation No. 385-5, Dept. of the Army, U.S. Armament Material Readiness Command, October 1979, Safety: Contamination, Decontamination and Disposal

†TB 700-4, Dept. of the Army, October 1978, Decontamination of Facilities and Equipment

documents; and 3) that as a result of the decontaminaton operations the Leaseback Area and a small portion of the GSA area (that is, the 237 sewer outflow region) have been cleared of explosives/explosive residue hazards, friable asbestos hazards, and other industrial safety hazards. The certifications also need to address the proper removal, transport, and final disposal of those containing PCBs and mercury that had been discovered in the Leaseback Area (and were not part of the original contract). Certification as to the proper operations of the asbestos repository and demolition rubble disposal site shall also be furnished.

6.2 BASIS FOR CERTIFICATIONS

The certifications are based on 1) the cleanness (acceptance) criteria presented in Section 3.3 of this report and 2) over 5,000 pieces of supporting data which verify the effectiveness of the decontamination. These data are presented in both the certification reports (see Figure 4) and in the USATHAMA Installation Restoration Data Management System.

6.3 CERTIFICATION DATA

Two types of certification data have been recorded. The first type involves Certipak data, which verified the effectiveness of the decontamination burn. Since the structures and areas decontaminated were subsequently demolished, the data site locations no longer exist. Therefore, these data have been incorporated only in the hardcopy certification reports (see Figure 4). The second type of data relates to structures/areas remaining in the Leaseback Area on completion of the project. These data are associated with the evaluation of buildings that were left standing and the soil areas tested for DNT contamination. These sites have been permanently marked in the structures/areas sampled, and the data have been entered into the USATHAMA Installation Restoration Data System.

6.4 CERTIFICATION OF THE LEASEBACK AREA

Figure 10 presents Rockwell certification that decontamination of the Leaseback Area has been conducted, specifically that the decontamination was performed; that it was performed in accordance with approved plans, SOPs, and applicable contract documents; and that the area is free of explosives/explosive residue hazards, friable asbestos which would cause a safety hazard, and other industrial safety hazards.

7.0 SUMMARY

The decontamination of the AAAP Leaseback Area was completed two months ahead of schedule and approximately 5% below contract value.

A total of 193 buildings, 407 tanks, and 445 sumps were decontaminated by burning. Approximately nine miles of the industrial sewer system serving the Leaseback Area were excavated and decontaminated by flaming; the resulting rubble was hauled to the rubble disposal area just north of the Leaseback Area. Nearly 1 ton of propellant grains from the 237 area was removed and burned.

Before starting decontamination operations, $\sim$21,000 ft^3 of friable asbestos, 186 oil switches containing PCBs, and 789 components containing mercury were removed from the buildings to be decontaminated.

The friable asbestos was packaged in plastic bags, sealed, and disposed of at the onsite asbestos repository located just north of the Leaseback Area. The oil switches containing PCBs and the components containing mercury were packaged, transported, and disposed of in accordance with applicable federal and State of Alabama hazardous waste disposal management regulations at the Chemical Waste Management disposal facility at Emelle, Alabama.

At the peak of the project (in the March through June time frame), approximately 80 people were employed on the project. Of these, approximately 60 were local and 20 were Rockwell. Of the 60 locals, 45 were field decon workers, with the remaining 15 being administrative/technical support personnel (secretaries, technicians, field coordinators, maintenance mechanics, etc.). The 20 Rockwell people were made up of:

- Nine operations personnel (four engineers and five crew leaders)
- One QA specialist

- Three material people (one procurement manager, one buyer, and one traffic and warehousing specialist)
- One safety officer
- Three analytical operations personnel (one laboratory manager, one data management specialist, and one chemist)
- One subcontract administration specialist
- One project administrator
- One project manager.

Of the nearly $1.6 million in outside procurements (material, supplies, major subcontracts, etc.), ∿84% went to small business concerns, well exceeding the initial small businness participation goal of 62%. Small disadvantaged business participation was 3.2%, well in excess of the original goal of 1.2%. Of all outside procurements, 85% were placed with Alabama firms.

Four lost-time accidents occurred during the decontamination operations. This translates to an accident rate* of 8. This is considered excellent when viewed in the light of national averages where normal construction activities experience an accident rate of 18 and white collar office work experiences an accident rate of 10.

Based on over 5,000 individual pieces of data, Rockwell has certified the Leaseback Area to be free of explosives/explosive residue hazards, friable asbestos which could be a safety hazard, and other industrial safety hazards. The data are presented in backup documentation to this report in the form of both certification reports (Figure 4) and data permanently stored in the USATHAMA Installation Restoration Data Management System. These certification data, coupled with Rockwell certification, provide USATHAMA with the basis for going forward to turn back the Leaseback Area to its owner, the Kimberly Clark Corporation.

---

*Accident rate is defined as the number of lost-time accidents for every 200,000 manhours worked.

8.0 CONCLUSIONS

As a result of the AAAP decontamination operations experience, several important conclusions have been drawn which should be useful in future projects of this type. The conclusions drawn from the experience are as follows:

- Detonations were heard during the burning of several of the buildings in the Leaseback Area, notably in the 112 series of buildings in the NC manufacturing area and in the 211 and the 234 series of buildings in the smokeless powder production area. These detonations validate the judgment that the only safe way to accomplish explosives decontamination is by burning the structures involved.
- The use of Certipaks is an excellent means for verifying the effectiveness of the decontamination. It is quick, positive, and lends itself to true assessment of the effectiveness of the burns. The use of Certipaks on future projects of this type is strongly recommended.
- The use of hand-held flamer rigs for decontaminating the interior to excavated industrial sewer pipes is quick and efficient. This approach is strongly recommended for follow-on projects of this type.
- The use of explosives for shattering floor drains is extremely effective in decontaminating these facilities. With a small effort, however, it is believed that the flamer rigs could be remotized and then used to accomplish the same result at lower cost. The main problem encountered with the use of detonating cord explosives for decontaminating the drains was the 1,000-ft exclusion area required during blasting operations. At times, this severely hampered other operations in nearby areas.
- During verification testing, removal of overhead process piping prior to decontamination burns was attempted using sheet

explosives. This approach was totally ineffective. Not only was it difficult to cut the pipe using sheet explosives, but the use of explosives above ground in the buildings often produced such severe structural damage that it hampered subsequent preparation activities within the building (such as loading of dunnage) because of the danger of accidents to decontamination personnel. If it is desired to remove overhead process piping, shaped charges should be used. Before they are used, however, it should be verified that structural damage using shaped charges is not excessive to the point where subsequent entrance to the building will have to be restricted.

In summary, the AAAP Decontamination Operations Project was a total success. The environmental survey conducted by ESE properly identified the contaminants within the area, the contract work scope was well defined, and decontamination operations proceeded smoothly. The importance of the environmental survey results and resulting contract work scope cannot be overemphasized relative to achieving a successful decontamination project.

APPENDIX A

Buildings Evaluated/Decontaminated

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 1 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
102 A	Acid tank farms	X				X	
102 B		X				X	
102 C		X				X	
104 B	Cotton dry houses		X			X	
104 C			X			X	
105 A	Nitrating houses		X			X	
105 B			X			X	
105 C			X			X	
106 A	Spent acid filter houses		X			X	
106 B			X			X	
106 C			X			X	
108 A	Boiling tub houses	X		X			
108 B		X		X			
108 C		X		X			
109 A	Pulping houses		X			X	
109 B			X			X	
109 C			X			X	
111 A	NC slurry tank houses		X			X	
111 B			X			X	
111 C			X			X	

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 2 of 11)

Building Number	Historical Usage	Contract Classification: Evaluate	Contract Classification: Decontaminate	Action Taken: Evaluate and Leave Standing	Action Taken: Evaluate and Demolish	Action Taken: Decontaminate and Demolish	Action Taken: Decontaminate and Leave Standing
112 A	Poaching tub houses		X			X	
112 B			X			X	
112 C			X			X	
113 A	Blending & final wring-ing houses		X			X	
113 B			X			X	
113 C			X			X	
115 A[b]	Chill water houses	X					
115 B		X			X		
115 C		X			X		
120 A	Valve pits	NL[a]	NL			X	
120 B		NL	NL			X	
120 C		NL	NL			X	
120-1AL	Saveall tanks		X			X	
120-1AR			X			X	
120-2AL			X			X	
120-2AR			X			X	
120-1BL			X			X	
120-1BR			X			X	
120-2BL			X			X	
120-2BR			X			X	
120-1CL			X			X	
120-1CR			X			X	

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 3 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
120-2CL	Saveall tanks		X			X	
120-2CR			X			X	
122 A	Wood pulp houses		X			X	
122 B		X				X	
201 A	Lag houses	X				X	
201 B		X				X	
201 C		X				X	
202 A	Dehydratingg houses		X			X	
202 B			X			X	
202 C			X			X	
202 E			X			X	
202 F			X			X	
202 G			X			X	
202 K	Alcohol tank farms	X				X	
202 L		X				X	
202 M		X				X	
203 A	Alcohol storage tank farm	X			X		
206 A	Ether mix houses		X			X	
206 B			X			X	
206 C			X			X	

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 4 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
207 A	Ether alcohol storage tanks	X				X	
207 B		X				X	
207 AA	Solvent receiving pump houses	X			X		
207 BB		X			X		
208 A	Mixer houses		X			X	
208 B			X			X	
208 C			X			X	
208 D			X			X	
208 E			X			X	
208 F			X			X	
209 A	Scrap rework house		X			X	
211 A	Horizontal screening & press houses		X			X	
211 B			X			X	
211 C			X			X	
211 D			X			X	
211 AB	Solvent recovery pump houses	X				X	
211 CD		X				X	

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 5 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
213 A	Solvent recovery car wash & dry house		X			X	
214 A1	Solvent recovery houses		X				X
214 A2			X				X
214 A3			X				X
214 A4			X				X
214 A5			X				X
214 A6			X				X
214 A7			X				X
214 A8			X				X
214 A9			X				X
214 A10			X				X
214 A11			X				X
214 A12			X				X
214 A13			X				X
214 A14			X				X
214 A15			X				X
214 A16			X				X
214 B1			X				X
214 B2			X				X
214 B3			X				X
214 B4			X				X
214 B5			X				X

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 6 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
214 B6	Solvent recovery houses		X				X
214 B7			X				X
214 B8			X				X
214 B9			X				X
214 B10			X				X
214 B11			X				X
214 B12			X				X
214 B13			X				X
214 B14			X				X
214 B15			X				X
214 B16			X				X
214 C1			X				X
214 C2			X				X
214 C3			X				X
214 C4			X				X
214 C5			X				X
214 C6			X				X
214 C7			X				X
214 C8			X				X
214 C9			X				X
214 C10			X				X
214 C11			X				X
214 C12			X				X
214 C13			X				X
214 C14			X				X
214 C15			X				X
214 C16			X				X

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 7 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
216 A		X			X		
216 B		X			X		
217 A	Knife grind & die shop		X			X	
218 A	Unload & screen house		X			X	
218 B			X			X	
218 C			X			X	
219 A	Dry houses (Cannon)		X			X	
219 B			X			X	
219 C			X			X	
219 D			X			X	
219 E			X			X	
220 A	Controlled circulation dryer houses		X			X	
220 B			X			X	
220 C			X			X	
220 D			X			X	
220 E			X			X	
220 F			X			X	
222 A	Powder transfer houses	X		X			
222 B		X		X			

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 8 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
226 A	Hydraulic & refrigeration house	X			X[c]	X[c]	
233 A	Screen clean house		X			X	
234 A	Vertical press houses		X			X	
234 B			X			X	
234 C			X			X	
234 D			X			X	
234 E			X			X	
234 F			X			X	
234 G			X			X	
234 AB	Solvent receiving pump houses	X				X	
234 CD		X				X	
234 EF		X				X	
234 GG		X				X	
235 A	Rifle powder dry houses		X			X	
235 B			X			X	
235 C			X			X	
235 D			X			X	
235 E			X			X	
235 F			X			X	

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 9 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
236 A	Sweetie barrel houses		X			X	
236 B			X			X	
236 C			X			X	
236 D			X			X	
237 A	Tray dryer houses		X			X	
237 B			X			X	
237 C			X			X	
237 D			X			X	
237 E			X			X	
237 F			X			X	
251 A	Activated carbon solvent system houses	X				X	
251 B		X				X	
257 A	DNT service house		X			X	
263 A	Loading dock	NL	NL	X[d]		X[d]	
501 NA	Service buildings	X				X	
501 NB		X				X	
501 NC		NL	NL			X	
501 PA		X				X	

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 10 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
501 PB	Service buildings	X				X	
501 PC		X				X	
501 S1		NL	NL			X	
501 S2		NL	NL			X	
501 DH		NL	NL			X	
601 A	Service building	X			X		
704 A	Service buildings	X				X	
704 E		X		X			
704 K		X				X	
704 L		X		X			
707 C	Service buildings	X				X	
707 D		X		X			
707 E		X		X			
707 F		X		X			
707 L		X		X			
707 M		X				X	
707 N		X		X			
707 R		X		X			
707 S		X		X			
707 T		X		X			
707 V		X		X			

TABLE A-1

BUILDINGS EVALUATED/DECONTAMINATED
(Sheet 11 of 11)

Building Number	Historical Usage	Contract Classification		Action Taken			
		Evaluate	Decontaminate	Evaluate and Leave Standing	Evaluate and Demolish	Decontaminate and Demolish	Decontaminate and Leave Standing
722 B	Service buildings	X				X	
722 BB		X				X	
722 C		X				X	
722 F		X				X	
722 N		X				X	
722 P		X				X	
727 A	Service buildings	X				X	
727 B		X				X	
727 F		X				X	
727 G		X				X	
727 Z		NL	NL			X	
Caustic mixers (2)		NL(2)	NL(2)			NL(2)	

[a]Not listed

[b]115 A did not exist

[c]Evaluation testing showed 226 A to be contaminated; it was subsequently decontaminated and demolished.

[d]Evaluation testing showed 263 A to be contaminated; 263A was flamed and then backfilled.

5056D-1jm

APPENDIX B

CRITERIA UPON WHICH TO BASE DECONTAMINATION PROCEDURES FOR AAAP LEASEBACK AREA

AD

TECHNICAL REPORT 8105

CRITERIA UPON WHICH TO BASE DECONTAMINATION PROCEDURES FOR AAAP LEASEBACK AREA

DAVID H. ROSENBLATT, Ph.D.
MITCHELL J. SMALL

Prepared for
U.S. Army Toxic and Hazardous Materials Agency
Aberdeen Proving Ground, MD 21010
Mr. Robert Breschi, Project Coordinator

by

U S ARMY MEDICAL BIOENGINEERING RESEARCH & DEVELOPMENT LABORATORY
Fort Detrick
Frederick, Maryland 21701

AUGUST 1981

Approved for public release;
distribution unlimited

U.S. ARMY MEDICAL RESEARCH and DEVELOPMENT COMMAND
FORT DETRICK
FREDERICK, MARYLAND 21701

NOTICE

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TECHNICAL REPORT 8105	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PRELIMINARY POLLUTANT LIMIT VALUES FOR ALABAMA ARMY AMMUNITION PLANT		5. TYPE OF REPORT & PERIOD COVERED Technical Report June 1980 - June 1981
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) DAVID H. ROSENBLATT, Ph.D. MITCHELL J. SMALL		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Medical Bioengineering Research & Development Laboratory, ATTN: SGRD-UBG, Fort Detrick, Frederick, MD 21701		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62720A 3E162720A835/AA/851
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research & Development Command ATTN: SGRD-RMS Fort Detrick, Frederick, MD 21701		12. REPORT DATE August 1981
		13. NUMBER OF PAGES 48
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Carcinogens; Dinitrotoluene; Environmental pollution; Hazards; Land contamination; Lead salts; Nitroaromatic compounds; Pollutant limit values; Risk assessment; Soil pollution; Tetryl; Toxicity; Trinitrotoluene

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of calculations by the Preliminary Pollution Limit Value (PPLV) method for 11 known or suspected soil contaminants at the Alabama Army Ammunition Plant, Childersburg, AL. These contaminants remain from World War II production activities. The results can assist Army managers in decisions involved with the disposition of the plant, now considered excess property. Specifically, soil limits are suggested for

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract (Continued)

release of land to unrestricted use and land use restrictions are suggested for existing levels of soil contaminations.

The pollutants of concern are: 2,4,6-trinitrotoluene; dinitrotoluenes; 2,4,6-trinitrophenylmethylnitramine; lead; 1,3,5-trinitrobenzene; nitrocellulose; 1,3-dinitrobenzene; diphenylamine; aniline; N,N-dimethylaniline; and nitrobenzene. PPLV values are computed for these substances for several possible future land use situations; subsistence agricultural (essentially unrestricted use); residential housing; apartment housing; industrial; and hunting lands. The PPLV values represent situation-specific soil levels, which based on the methodology and best-available data would be generally considered to present no hazard to humans.

The method suggests that vegetable uptake of pollutants could be the pollutant transmission route which causes severest restriction of land use. In terms of known pollutants and known contamination levels, 2,4-dinitrotoluene and lead are the pollutants of main concern; soil levels of these pollutants are in excess of PPLV values for most land use situations.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

TABLE OF CONTENTS

FIGURE

TABLES

INTRODUCTION

The US Army controls large parcels of real estate that are no longer used for military purposes and would not be reactivated in time of full-scale war. Ordinarily, these parcels are excessed by the Army and transferred to the General Services Administration for ultimate disposition, such as sale to non-government purchasers.

Several existing installations are inactive ammunition plants. For the most part, they were procured, constructed and operated for World War II activities. They operated with the conventional manufacturing and waste treatment technology of the times. Explosives removal in wastewater was confined, if at all, to recovery of screenable material. Waste solids were burned in open areas. Portions of these plants and surrounding land were contaminated with chemicals involved in explosives production. Following the end of the war, military industrial operations ceased at these installations. Alabama Army Ammunition Plant is such an installation.

Awareness of the adverse consequences of using land with past chemical production history is very acute in 1981. Land to be returned to unrestricted use must not have residual chemical contaminants at levels that might be harmful to its future inhabitants. Procedures for land renovation, including physical removal and replacement of contaminated soil mass, must meet this goal. The potential costs of renovation efforts must be balanced against the expected benefits. The costs would be borne by the general public, while the benefits would be perceived as locally accrued. Less costly alternatives could be considered, such as restricted land use.

A decision as to how far to go in land renovation depends on what contamination exists and what contamination would be allowable for specified or unrestricted land use. Procedures to derive acceptable soil contamination limits relative to potential land use have not been extensively studied. The authors have participated in an early effort to derive an organized approach to such decision making.[1] The result of this effort was the preliminary pollutant limit value method (PPLV), which has been presented in the open literature.[2]

This report documents the application of the PPLV method to the Alabama Army Ammunition Plant situation. It was prepared to assist the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) in making decisions concerning disposal of Alabama Army Ammunition Plant real estate.

REPORT ORGANIZATION AND CAVEATS

The Site Background section describes the situation existing at the Alabama Army Ammunition Plant in terms of past and present use, and known contamination studies. The section on Substances Selected for Study presents the contaminants specifically addressed in this PPLV method application. The section on Overview of the PPLV Method describes the approach for persons unaware of its formulation, equations, and assumptions. The section on Land Use Scenarios and Pathways outlines various scenarios for land use and attendant human exposure pathways. The section on Scenario-Related Data for Subsequent Analyses documents data required for subsequent computations. The section on Scenario Analysis for Land Use Intensity provides estimates of land

use intensity for the selected land use scenarios. Such estimates allow for a detached cost/benefit perspective of the extent of land renovation that would be required with each scenario. The next section documents the single pathway preliminary pollutant limit value (SPPPLV) computations. The section on PPLV Computations discusses the limiting contaminant concentration values derived through use of the PPLV method and their relation to existing land contamination. The last section provides recommendations for PPLVs related to the Alabama Army Ammunition Plant.

The PPLV method incorporates reasonable assumptions of toxicological data and the modes of human exposure into a computational framework whereby acceptable soil contaminant levels can be estimated. Involved mathematical models are avoided, inasmuch as the available data generally do not support a more complex approach. Toxicological data are derived from studies that may vary widely in relevance to humans and in scientific credibility. The analysis requires several types of data that are either averaged, safe-sided, or scenario-specific. Some numerical inputs should find easy acceptance, while others are based on scanty documentation and guesswork. Efforts are continuing to refine such data. Land contamination values so arrived at should not be construed as official recommendations of the Office of the U.S. Army Surgeon General. Rather, they are the end results of a thought process that the decision-maker may wish to modify, and for which he retains ultimate responsibility.

The temptation to endow a PPLV with an absolute and inviolate nature should be avoided. The PPLV is use-scenario oriented; different PPLVs for the same contaminant are computed for different scenarios. Moreover, the tentative nature of the data elements are such that more refined data may cause a drastic change in a PPLV.

SITE BACKGROUND

Alabama Army Ammunition Plant is located in Talladega County, on the banks of the Coosa River, about 4 miles north of Childersburg, 40 miles southeast of Birmingham, AL. The terrain is level to rolling and generally suited to pasture and timber. Elevations range from about 400 to 580 feet above sea level. The present area is 5,168 acres. The plant was operated between April 1942 and August 1945. It was placed on standby basis until 1975, and then declared to be excessed. The land has been largely used for timber and pulpwood.[3]

The average rainfall in nearby Anniston, AL, is 53 inches.[3] The average depth of sedimentary (limestone) bedrock is 40 to 60 feet, penetrated in places by sinkholes. The limestone bedrock is overlain by silty sandy clays of generally low permeability.[4] The water table, draining to the Coosa River, is very shallow (8 to 20 feet). Any wells dug for a water supply would be to the aquifer below bedrock, and would be of such construction as to prevent contamination from soil at upper levels.[4] The surface soil contains only about 1% organic matter.[5] The background soil-lead content in the local area is about 30 mg Pb/kg.[6]

Figure 1 is a map of the plant; it shows and names various areas in which production or waste-disposal activities were located. The numerical

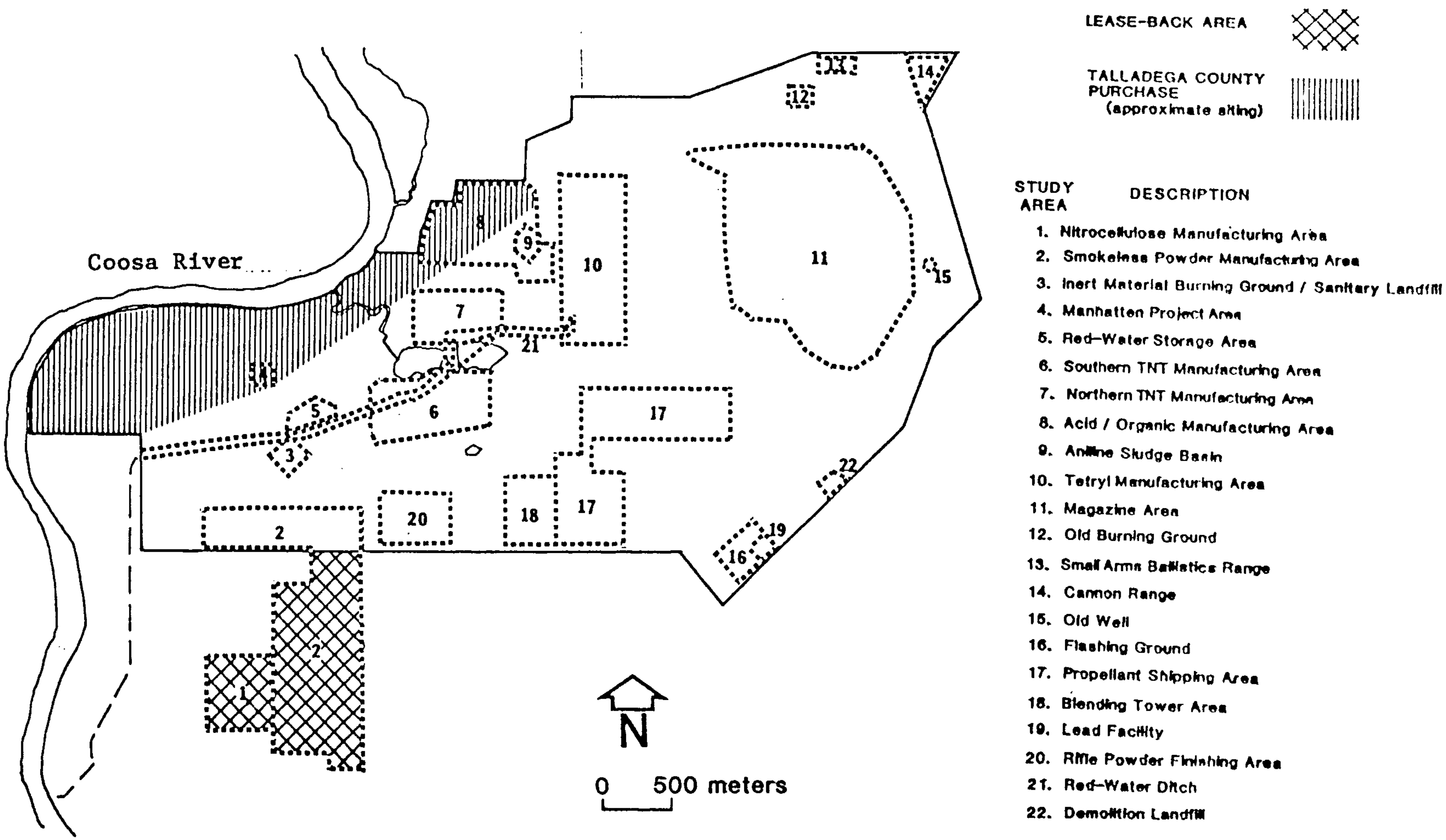


Figure 1. Location of Designated Study Areas.[7]

designations of Figure 1 will be used in the text. The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) has contracted to have soil surveys performed at these areas of the plant. Table 1 summarizes the results of such surveys as of November 1980. Based on information from USATHAMA personnel, about 94 acres are considered to contain the bulk of the contamination.[6] Contamination in the old production areas is generally scattered and highly localized. Burning grounds and landfills have intense areas of contamination. For example, areas 12, 16, 19, and 22 involve approximately 14 acres of land considered contaminated, but contain the majority of the contaminated soil. Estimated soil volume for these four areas is 69,000 m^3.[7]

Additionally, two sections of land are of particular interest to the Army:

1. The cross-hatched section in Figure 1. This land (area 1 and the southern portion of area 2) was purchased by the Kimberly-Clark Company. The land was found to be contaminated, and was leased back to the Army for clean-up operations. This section is not included in the 94 acres cited above.

2. A 300-acre region comprising areas 4 and 8, and portions of the property to the west and north of these areas. This land is being considered for sale to Talladega County as the site of a gasohol plant.[8]

KNOWN OR SUSPECTED POLLUTANTS SELECTED FOR STUDY

Based on the site surveys listed in the section on Site Background, on historical records, and on discussions with USATHAMA personnel,[5] the following substances were selected for PPLV development:

1. TNT, a high explosive.

2. DNT. The 2,4-isomer is used primarily in smokeless powder formulations. Moreover, in the manufacture of TNT, 2,4-dinitrotoluene is present as a by-product at about four times the concentration of 2,6-dinitrotoluene.[9]

3. Tetryl, a booster explosive.

4. Lead (to include inorganic salts). The salts were probably derived from burned smokeless powder mixtures and perhaps from environmental action on metallic lead.

5. TNB, primarily a product of TNT degradation in the environment.

6. Nitrocellulose, the base for all propellant formulations.

7. 1,3-Dinitrobenzene, a suspected by-product in the production of TNT. It is probably formed from the nitration of impurity benzene in the raw material toluene.

8. Diphenylamine, an ingredient in smokeless powders.

9. Aniline, the starting material for N,N-dimethylaniline, an intermediate in the production of tetryl.

TABLE 1. ALABAMA ARMY AMMUNITION PLANT SOIL CONTAMINANTS: SUMMARY OF SURVEYS[5,6,7]

Contaminant	Area	Observations
2,4,6-Trinitrotoluene (TNT)	3	a
	6	b
	7	b
	12	<37-694 ppb[c]
	16	<37-2350 ppb
2,4-Dinitrotoluene and 2,6-Dinitrotoluene (DNT)	2 (lease-back)	<112-1440 ppb
	6	b
	7	b
	11	208 ppb in 1 of 18 samples
	12	<102-875 ppb
	16	<102-1845 ppb
	17	208 ppb in 1 of 28 samples
	20	<112-6095 ppb
2,4,6-Trinitrophenyl-methylnitramine (tetryl)	10	a
	16	<257-6624 ppb
	20	> 500 ppb
	22	554 ppb in 1 of 2 samples
Lead (elemental and salts)	1 (lease-back)	<10-3000 ppm
	4	300 ppm in 1 of 2 samples
	12	23-1610 ppm
	13	Metal in bullets
	16	50-2000 ppm
	19	70 PPB-1600 ppm
	22	354 and 2160 ppm in 2 samples, metallic lead visible
1,3,5-Trinitrobenzene (TNB)	2 (lease-back)	614 ppb
	6	b
	7	b
	8	b
	11	<368-2540 ppb
	16	<368-3920 ppb
Nitrocellulose	16	<42-65 ppm
	17	139 ppm
	18	56 ppm
	20	1290-1490 ppm

a. Crystalline material suspected of being this contaminant is visible in soils in this area.

b. Reported in references 5 and 6; numerical data not available.

c. 1 ppb = 1 μg/kg; 1 ppm = 1 mg/kg.

10. N,N-dimethylaniline, the immediate precursor in the production of tetryl.

11. Nitrobenzene. The source of this substance is not known, but it has been reported at Area 22.[5] The compound may have been a precursor to aniline.

OVERVIEW OF THE PPLV METHOD

The PPLV method was developed to address the land and water pollution situation that had arisen from discontinued military and civilian production activities at Rocky Mountain Arsenal, CO.[1] Several pollutants were suspected of being leached to groundwater, and the State of Colorado issued a "cease and desist" order to halt further contamination. A method was needed to provide rough estimates of acceptable groundwater and soil levels of contaminants.

The PPLV method is primarily based on the premise that human life is to be safeguarded from the adverse effects of pollutants. Where soil is the medium of concern, computations of the method are involved with:

1. Determination of an acceptable daily dose of a substance to humans,

2. Computation of the corresponding soil level that could produce such a dose for each of specified pathways through which the substance interacts with man, and

3. Computation of a soil level for the substance based on concurrent consideration of all the different pathways.

The PPLV method entails relatively uncomplicated methods. This is in recognition of the scarity of information in the literature for other than regulated or special-concern substances such as heavy metals and pesticides. Estimated soil limits can be projected from such a scanty data base, and major areas of data deficiency can be highlighted. The method is highly assumptive, a usual consequence of simplicity in models. Where sufficient information indicates that the assumptions are not valid, more sophisticated models should be considered; these can usually be incorporated within the PPLV framework.

The first step is to determine which substances and soil-human pathways are to be considered. Substance consideration begins with a review of past land utilization, and should be augmented by on-site sampling. Logic may indicate deletion of some substances, notably volatile solvents, while environmental chemistry considerations may suggest that certain others have disappeared. A pathway is selected if there is reasonable expectation, given the local situation, that a given substance in the soil can be transmitted to man via ingestion or inhalation. Pathways that would exist in hypothetical future land use situations are also candidates for selection. The selector must temper his decisions with the realization that additional investments of time and research are incurred with additional pathway considerations. Sometimes cursory consideration of a speculative pathway will indicate that that pathway is not meaningful, compared to co-existing pathways.

The second step of the method is to identify and collect those data required for computations. The one datum common to any PPLV computation is an acceptable daily dose (D_T) to humans.

An initial determination is required to decide whether to consider a substance as a potential carcinogen (more properly "oncogen," to human beings, as it will determine the procedures and significance of D_T. A substance is considered a potential carcinogen if any of the following statements apply.

1. It is treated as such in U.S. Environmental Protectiodn Agency water quality criteria documents.[10].

2. It has been found carcinogenic in comprehensive lifetime bioassays on two rodent species.

3. It is listed as a category I or II substance in the "suggested list of carcinogens" for inclusion in 29CFR1990.[11]

It is generally accepted that non-carcinogens can be ingested or inhaled at some non-zero dose level and have no harmful long-term effect. D_T, in this case, is an estimation of that dose level. Carcinogens are generally agreed to have the theoretical potential for causing cancer at any dose level. On the strict basis of preventing harmful human effects, no carcinogenic contaminant should be retained in soil. However, the attainment of a "zero" level by land renovation could be astronomical in cost.

A more dispassionate approach is to assess a substance's dose-risk relationship for carcinogenic effects. Carcinogenic risk (R) is expressed in terms of R = probable additional risk of cancer in the lifetime of an exposed human. Alternatively, R implies one probable additional case of cancer in the lifetimes of 1/R exposed persons. Commonly used dose-risk relationships employed by the U.S. Environmental Protection Agency[10] presume that dose and risk can be assumed linearly related in a region about the zero dose.

Risk can be computed for human activities. The authors observe that risk levels of 10^{-2} to 10^{-4} are associated with voluntary actions, such as injury or death from automobile accidents. Risk levels in the range of 10^{-4} to 10^{-7} appear to be associated with involuntary mishaps, for example, injury or death from such "acts of God" as tornados, floods or bee stings. The authors perceive that public policy now developing for dealing with carcinogenic substances in the environment is based on the rationale that such substances should not pose risk levels greater than those from involuntary mishaps. This rationale amounts to a decision of expediency, which is relevant to the Army land-disposal situation. A welfare-economic decision is involved, where public funds are spent to directly benefit a few individuals. Some balance is required between the carcinogenic risk associated with substances on such land, the benefits from use of such land, and the costs of providing the land. No formal policy has evolved as to how this balance is to be determined. One factor that would be involved is the size of the population at risk. This is part of the rationale for making the computations in the section on Scenario Analysis for Land Use Intensity.

D_T estimation for a non-carcinogen involves review of the toxicological literature with the intent of finding relevant no-effect dose information. A preference literature approach based on the type of information available is recommended to best assure use of that which is most relevant. Such literature, in most to least preferable order, is in part:

1. Acceptable daily intakes (ADI) recommended by the joint WHO/FAO expert committee on food additives.

2. Drinking water standards.

3. Human ingestion water quality criteria such as those summarized in reference 10.

4. Threshold limit value (TLV) documentation for substances in workroom air.[12]

5. Published lifetime mammalian feeding studies (chronic feeding studies).

6. Published long-term (approximately 90 days for rats or mice) mammalian feeding studies.

7. Published one-dose (acute) oral toxicity studies on mammals.

Regardless of the literature used, the contents should be critically reviewed.

The mathematical relations involved in computing D_T from such information have been listed,[2] and with the exception of the D_T - TLV relation, are used herein. That relationship has been revised to the form

$$D_T = TLV \times RB' \times (5/7) / (100 \times BWA) \tag{1}$$

where D_T is in mg/body weight/day; the TLV is in mg substance/m^3 of air; RB′ is the workday breathing rate (12.1 m^3/day); (5/7) adjusts from a workweek to a calendar week, and BWA is adult body weight (70 kg).* The constant 100 is included as a safety factor to provide for sensitive humans (the young and elderly), and for the involuntary nature of such exposure. Numerically, Equation 1 is:

$$D_T = 0.0012 \times TLV \tag{2}$$

The next step involves computation of the single pathway PPLVs (SPPPLVs). The assumption at this step is that each pathway is the only pathway that transmits the substance of concern from soil to man. Each pathway is treated as a consecutive compartmental model through which the substance passes. For example, the pathway "livestock consumption" or ingestion of meat from animals fed plants grown in contaminated soil involves pollutant transfer from soil to plant and thence to animal. In the absence of refined information, each transfer is assumed to be characterized by a partition coefficient. The relations derived are of the form:

$$C_{si} = IF \times D_T / K_i \tag{3}$$

* Unless otherwise specified, the nomenclature used in this report follows that of references 1 and 2. The data used here are from reference 1. All symbols in this report are included in the glossary.

where C_{si} is the computed SPPPLV for pathway i in mg pollutant/kg soil; IF is an "intake factor" that typically includes information about human weight and the daily rate of ingestion; and K_i is the overall partition coefficient for the pollutant between soil and the matter ingested by man. In the above example, partition coefficients K_{sp} (soil to plant) and K_{pa} (plant to animal) are involved, and $K_i = K_{sp} \times K_{pa}$.

The PPLV is computed from its component pathway's SPPPLVs. Heretofore, each pathway has been considered as the only pathway by which the substance reaches man. In fact, each pathway provides a portion of D_T; all pathways taken together provide D_T. For each pathway, the relationship between soil content and D_T can be written as

$$SPPPLV_i = C_{si} = R_i \times D_T \tag{4}$$

where, by comparison to Equation 3, $R_i = IF/K_i$. To compute PPLV from these equations, two requirements are that

$$\sum D_{Ti} = D_T \tag{5}$$

where D_{Ti} is the portion of D_T delivered by each pathway for a PPLV value of C_{sf}, and that

$$R_i \times D_{Ti} = C_{sf} \tag{6}$$

Equations 5 and 6 are analogous to direct current parallel resistance circuit equations where C_{sf} is a "potential," D_{Ti} is a "current" and R_i is a "resistance." From this analogy, the following equation results:

$$C_{sf} = D_T/ \left(\sum 1/R_i \right) \tag{7}$$

Through substitution of Equation 4 to eliminate R_i in favor of C_{si}, the PPLV based on component SPPPLVs is:

$$C_{sf} = 1/ \left(\sum 1/C_{si} \right) \tag{8}$$

or

$$PPLV = 1/\left(\sum 1/SPPPLV_i \right)$$

In the treatment developed above, potential difficulties have been perceived for compounds that were mutagenic to micro-organisms (Salmonella) in the Ames battery of tests, but for which oncogenesis had not otherwise been established.* Such a manifestation of mutagenicity enhances the desirability of carrying out chronic toxicity testing in at least two mammalian species. The proposal has been made* that any D_T-value obtained for such a compound by the procedures described above (which are herewith collectively desginated "method 1") should be reduced by a factor of 100 ("method 1"), pending acquisition of enough information to clear the compound of implied oncogenicity or to provide sufficient data to permit oncogenic criteria levels to be established by accepted procedures.

---

* Comments and "subjective" proposal to use a factor of 100, by Mr. Jesse J. Barkley, Jr., Acting Environmental Program Coordinator, Environmental Protection Research Division.

LAND USE SCENARIOS AND PATHWAYS

Land use scenarios and component pathways were selected in the course of discussions between the authors and USATHAMA.[6] These selections appear in Table 2.

Several assumptions were made in deciding these:

1. Water pathways would not be addressed. This would have involved ingestion of water that had been in contact with contaminated soil. The rationale used was that well water would come from an aquifer below bedrock (see Site Background section); at the depths involved, the groundwater would not contact contaminated soil. Fish consumption was also neglected. No significant utilization of local surface water resources for that purpose was anticipated.

TABLE 2. LAND USE SCENARIOS AND PATHWAYS CONSIDERED

	Pathways				
Scenarios	Vegetable Consumption	Livestock Consumption	Dairy Consumption	Soil Ingestion	Dust Inhalation
Subsistence agriculture	X	X	X	X	
Residential housing	X			X	
Apartment housing				X	
Industrial					X
Hunting		X			
Timber harvesting					X

2. The present study would be restricted to the approximately 94 acres considered to involve the bulk of contaminants at the plant.

SCENARIO DISCUSSION

The subsistence farming scenario assumes that the 94 acres of land would be farmed in such a manner that the population could derive the bulk of its dairy, meat and vegetable requirements. The acreage taken up in houses, barns, storage silos, etc. is not subtracted from the total. Moreover, the persons involved consume meat in lieu of fish or poultry.

The residential housing scenario assumes that the 94 acres of land is subdivided for individual housing units. The families are presumed to derive the major source of their vegetable diet throughout the year from home gardens.

The apartment housing scenario treats the case where the 94 acres of land is used for more intensive human habitation than above. It is assumed that the land is not used for any food-producing activities.

The industrial use scenario involves no permanent habitation on the 94 acres of land. Industrial use is anticipated to involve considerable outdoor activity for selected workers. The major concern is with inhalable dust raised from materials-handling vehicles.

The hunting scenario involves the absence of any human activity on the 94 acres of land except for the hunting of non-domesticated animals, specifically deer. Venison would augment the meat diet of the hunter's family. During a year, a family would consume the venison of one deer.

Timber harvesting is not discussed in detail as a separate scenario. It may be considered as a very occasional activity, otherwise resembling the industrial scenario.

PATHWAY DISCUSSION

Vegetable consumption is referred to as pathway 1. This involves the use of indigenously-grown crops as the major source of vegetable diet throughout the year. This is somewhat safe-sided since not all vegetables can be preserved. The equation applicable to pathway 1 is:

$$C_{s1} = BWA \times D_T/(VC \times K_{sp}) \tag{9}$$

where C_{s1} is this SPPPLV in mg pollutant/kg dry soil; VC is the kg/day of vegetable matter ingested daily (dry weight basis);* and K_{sp} is the partition coefficient for the pollutant between soil and plant. K_{sp} has units of mg pollutant per kg dry plant weight/mg pollutant per kg dry soil.

Both livestock consumption and venison consumption are considered special cases of Pathway 2. Livestock consumption involves the use of pigs or beef cattle for the family meat supply. The animals consume crops grown on contaminated land. In terms of per-capita United States meat consumption, these animals account for over 95% of the source animal supply.[13] Relative consumption of beef to pork is slightly less than a 2:1 ratio. The either-or approach adopted will show which animal provides the worse-case situation.

In the hunting scenario, Pathway 2 is associated with the incidental consumption of venison from deer. These animals, unlike domesticated cattle, can wander over an unrestricted land area including uncontaminated land. The SPPPLV for deer is subject to adjustment for this difference.

---

* This version differs somewhat from that used in references 1 and 2. Here, vegetable and meat information is used directly; previously, this information had been estimated as a fraction of overall diet.

The equation applicable to pathway 2 is:

$$C_{s2} = BWA \times D_T/(MC \times K_{sp} \times K_{pa}) \tag{10}$$

where C_{s2} is this SPPPLV in mg pollutant/kg dry soil; MC is the kg/day of meat consumed;* and K_{pa} is the partition coefficient for the pollutant between plant and meat. K_{pa} has units of mg pollutant per kg meat/mg substance per kg dry soil. Equation 10 assumes that a grazing animal does not get appreciable pollutant ingested along with soil in ingested plant material. Appendix A includes a computation of the soil contribution when $K_{sp} = 1$, and suggests that it is minor enough to be neglected.

Dairy consumption will be referred to as Pathway 3. Dairy products do include items such as butter, cheese and ice cream. Even in rural Alabama it is unlikely that a family would produce these items from milk. Thus, an assumption that all dairy products in the diet come from the milk of cows fed plants grown on contaminated soil is somewhat safe-sided. The equation applicable to this pathway is

$$C_{s3} = BWA \times D_T/(DC \times K_{sp} \times K_{pa} \times K_{ad}) \tag{11}$$

where C_{s3} is this SPPPLV in mg pollutant/kg dry soil; DC is the kg/day of ingested dairy products; and K_{ad} is the partition coefficient for a substance between animal fat and milk fat, expressed in mg pollutant per kg of milk fat/mg contaminant per kg animal fat. Organic comounds may preferably distribute to milk fat as contrasted to animal fat. K_{ad} provides for a calculation of this distribution.

Soil ingestion is referred to as Pathway 4. This pathway is restricted to young children. The most prevalent mode of soil ingestion is by incidental means in outdoor play activities. This situation will be considered here. The applicable equation is:

$$C_{s4} = BWC \times D_T/SC \tag{12}$$

where C_{s4} is this SPPPLV in mg contaminant/kg dry soil; BWC is a child body weight in kg; and SC is the kg/day of dry soil consumed.

An unusual condition, the abnormal ingestion of large amounts of non-food substances is called "pica." Pica is perhaps nutritional or psychological in cause.[14] Attention has been focused on pica owing to inner-city children's habits of eating peeling paint flakes from old buildings, which have a high lead content. The percentage of children with pica is not well-known; estimates of 6 to 50% in young children have been advanced.[15] The authors assume that nutritional or other factors that may be conducive to pica in small children will not be applicable in the scenarios considered.

---

* This version differs somewhat from that used in references 1 and 2. Here, vegetable and meat information is used directly; previously, this information had been estimated as a fraction of overall diet.

Dust inhalation is referred to as Pathway 5. This involves the exposure of outdoor workers to contaminants via inhaled dust. Various occupational scenarios could be specified; the approach taken here is to model one rather dusty environmental situation. The result is a conservative-sided SPPPLV. Alternative occupations such as timber harvesting could be compared to the model and a conclusion drawn as to the applicability of the model computation (see Discussion). The equations for this pathway are more complicated than for the previous ingestive pathways, and will be developed in the section on SPPPLV Computations for Organic Substances.

SCENARIO-RELATED DATA FOR SUBSEQUENT ANALYSES

The data base for populations associated with land use scenarios and PPLV computations is rather extensive. For clarity, scenario-specific information is presented here in order of use in subsequent sections. Where information is associated with equation variables presented in the text, the symbols are also shown. All symbols used in the text appear in the glossary.

For many factors, alternative literature sources exist that could provide somewhat different values. The authors consider the values used as reasonably representative of the "real world." Ideally, factor data highly representative of a specific locality should be used. However, for the implied precision of PPLV results here, the resource expenditures to refine these data did not seem to be justified.

FACTORS FOR LAND-USE POPULATION INTENSITY COMPUTATIONS

Item	Value	Reference	Remarks
Human Consumption Factors			
Dairy (DC)	0.756 kg/day	16	18-year old male basis
Vegetable (VC)	0.459 kg/day	16	Basis as above, includes "garden fruits" such as tomatoes and green peppers
Meat (MC)	0.290 kg/day	16	Basis as above, assumes replacement of fish and poultry in the model diet by beef or pork
Animal Factors			
Milk production	18.44 kg/day	17	
Dairy cow grazing area	2.5 acres	18	
Beef cow grazing area	2.0 acres	19	
Life of beef cow	24 months	20	
Beef yield per animal	271 kg	21	
Pork yield per animal	63.6 kg	22	
Life of pig	6 months	22	
Corn eaten by pig	900 lb (lifetime)	22	
Vegetable Factors			
Yield per acre	4540 kg/year	23	Assumed applicable for vegetables
Corn yield for pigs	82 bushels/acre	24	1 bushel = 55 pounds
Population Density Factors			
Residential housing	15 people/acre	25	light residential
Housing units in apartments	6 units/acre	26	3 floor walk-up
Persons per family	3.75 - 4.0		Authors' estimate
Others			
Deer kill at Alabama Army Ammunition Plant	202/year	3	

FACTORS USED IN SPPPLV COMPUTATIONS

Item	Value	Reference	Remarks
	Animal Fat Contents (FA)		
Fat fraction in beef	0.30	22	
Fat fraction in pork	0.45	22	
Fat fraction in venison	0.20		Authors' estimate
Fat fraction in milk	0.0391	17	
	Human Data		
Adult weight (BWA)	70 kg	10	
Work-day air volume inhaled (RB')	12.1 m^3	1	
2-yr child weight (BWC)	12 kg	27	
Adult consumption factors	See note 1		
2-yr child consumption factors			
Dairy	0.56 kg/day	16	
Meat	0.136 kg/day	16	Includes fish and poultry
Vegetables	0.125 kg/day	16	Includes "potatoes and other vegetables"
Soil ingested by 2-yr old	100 mg/day	28	See note 2
	Other Animal Data		
Live cattle weight	542 kg	17	
Live pig weight	109 kg	22	
Forage intake by cattle	16.5 kg/day	17	Dry weight basis
Soil intake by cattle	0.72 kg/day	29	See note 3
Live deer weight	83 kg		Authors' estimate, 15% of cattle weight
Venison yield	44 kg/animal		Authors' estimate, note 4
Percent of time deer occupy contaminated land	10%		Authors' estimate
	Vegetable Data		
Dry weight fraction	0.16		See note 5

1. Human consumption factors as shown in tabular data on previous page.
2. Soil consumption by 2-year old children is understandably difficult to quantify. Estimated soil or paint chip ingestion for pica are of the order of two to five or more times the level assumed here.[15,28]
3. Based on studies of pasture-fed cattle in New Zealand. Variation by a factor of least 2 may be expected as the result of variations in the amount of supplemental feed (without soil) and grazing intensity.
4. Dressed deer kills (animals already eviscerated) weigh about 66 kg in the Frederick, MD area. The authors surmise that 2/3 of this weight is ultimately consumed.
5. Based on authors' computations with representative per capita vegetable consumption values[13] and dry weights[30] of individual items.

SCENARIO ANALYSIS FOR LAND USE INTENSITY

This section provides human population figures associated with each scenario. Such figures may be of value in assessing the costs and benefits of a land renovation decision. They are intended as rough estimates. The data base is in the subsection on Factors For Land-Use Population Intensity Computations.

SUBSISTENCE AGRICULTURE

The area per person for each component of the scenario is computed.

Dairy

Daily milk production of 18.44 kg will provide for the needs of 24.4 persons. Based on 2.5 acres/cow, 0.103 acre of land is required per capita.

Vegetables

Based on a 4540 kg/year yield per acre, and an annual consumption per capita of 167.5 kg, 0.037 acres of land provides for the needs of each consumer.

Meat

Based on data in the subsection on Factors For Land-Use Population Intensity Computations and the subsection on Factors Used in SPPPLV Computations, one slaughtered beef cow will provide 1.28 persons' meat supply for 2 years. Based on 2 acres/animal, the net acreage per capita is 1.56. The actual acreage could be considerably higher, especially if a breeding herd is maintained.

The yearly meat needs of 1.20 persons can be provided by two pigs (one slaughtered each 6 months). One acre of land provides 4,510 lb of corn/year, which can feed five animals. Accordingly, on a per capita basis, 0.33 acres is required.

A larger population per acre can be accommodated with a pork-based meat supply than with a beef-based meat supply. On a per capita basis, 0.47 acres of land provides the dairy, vegetable and meat requirements. Assuming all 94 acres are so used, as many as 200 persons could be supported.

RESIDENTIAL HOUSING

An assumed 15 person/acre density would involve 1,410 persons residing on the 94 acres of concern. The vegetable needs for 15 persons requires 0.56 acres. If one considers each acre to have four homes, and the land needs for driveways and streets, most of the unused land would be involved in vegetable gardens.

APARTMENT HOUSING

Based on six units per acre, a population density of 23 persons per acre is estimated; on 94 acres, 2,160 persons could be housed.

INDUSTRIAL USE

The authors' judgment is that a maximum of 200 persons would be at risk to dust inhalation.

HUNTING

Based on recent deer kill numbers and a typical family size, about 750-800 persons could be involved.

SPPPLV COMPUTATIONS

SPECIAL CASES

Of the 11 substances chosen, data for nine are processed by typical methods. Data for the two others requires different approaches.

Nitrocellulose is a highly insoluble, fibrous material. Its toxicity has been well-studied and such studies have been reviewed by Dacre.[31] The material acts as inert dietary bulk, and any adverse responses that were seen in small laboratory animals appear related to physical blockage of their intestinal tracts. Accordingly, no D_T-based PPLV related to ingestion can be devised. On the other hand, nitrocellulose appears amenable to PPLV treatment in the industrial use scenario/inhalation pathway. Nitrocellulose is produced from cotton linters, and it appears that nitrocellulose effects would be due to its fibrous substrate. A TLV recommendation of 1 mg/m^3 for cotton dust[12] has been established, and this seems appropriate for nitrocellulose.

Lead is ubiquitous. Lead pollution has been well-studied, and certain generalizations can be made:

1. Children present a high-risk group for ingestion pathways.

2. The intake of lead from soil by plants is not highly related to the lead content of soil.

3. Lead is selectively stored in animal organs such as bone, liver and kidneys.

Accordingly, the approach taken for lead will be more in-depth than indicated by the equations in the section on Land Use Scenarios and Pathways.

Consideration must be given for a model 2-year old child as well as for the model adult considered in the typical PPLV method; different pathways may be critical for adults and children within the same scenario. Moreover, child considerations may be the more stringent in determining a PPLV. A recommended safe ingestion level for all food and drink of 600 μg Pb/day for adults appears a reasonable starting point for a model adult.[32] Estimated lead intakes from dietary sources not specifically considered must be deducted from this level. Adults ingest lead in such diet items regardless of scenario. Water and beverages (other than dairy-derived) are presumed to provide 25 μg Pb/day, based on estimates in reference 33. Other dietary components,

primarily fruits, grains, and cereal products, are assumed to provide an additional 40 μg Pb/day, based on estimates in reference 16. This leaves 535 μg Pb/day for intake from the dietary components discussed herein.

A recommended safe ingestion level of 300 μg Pb/day for 1- to 3-year old children has been suggested,[34] apparently on the basis of intakes and the corresponding lack of observed harmful effects. This level has been criticized for children at the lower ages; Mahaffey[34] has recommended 150 μg Pb/day for 6-month to 2-year old children. Paradoxically, the adult level above, when simply extrapolated on a weight basis to a 2-year old child, indicates a 103 μg Pb/day level. As a compromise, a starting lead intake of 125 μg PB/day is adopted here. Measured lead contents in water, grain, fruits, and cereal products,[16] add up to about 30 μg Pb/day intake in a model 2-year old child's diet.

The industrial use scenario presupposes exposure of a less sensitive population through the inhalation route. For occupational situations, an "action level" of 30 $\mu g/m^3$ has been established.[14] If the lead concentration in air exceeds this level, an employer must commence passive actions (monitoring, medical surveillance and employee training). Due to the rather extensive human studies of lead involved in this regulation and the technical and legal review afforded it, 30 $\mu g/m^3$ is used in calculating permissible levels for inhalation exposures.

D_T-VALUES

For TNT, an in-depth review of current toxicological studies was undertaken by Dacre.[31] The most revelant value for D_T was a no-effect level of 1.4 mg/kg/day based on a 90-day rat feeding study. The estimated D_T for TNT is therefore 1.4×10^{-3} mg/kg/day.[2] This is a "method 1" calculation (see p. 11). Owing to the observation of microbial mutagenesis in an Ames battery of tests,[34a] a "method 2" calculation was also made, giving a D_T of 1.4×10^{-5} mg/kg/day. Chronic toxicity testing is currently being pursued on TNT in three mammalian species. When this process has run its course, and the results have been evaluated, it should be possible to provide a definitive value of D_T if TNT is not oncogenic, or a criterion-dependent value if it is.

The estimated human effects of DNT, particularly 2,4-dinitrotoluene, are well documented in recently-issued water quality criteria.[10] This substance is considered a potential carcinogen. The authors consider a risk of 10^{-5} as appropriate to land use scenarios at Alabama Army Ammunition Plant; for this risk level the value of D_T computed from criteria data is 3.2×10^{-5} mg/kg/day.

Tetryl has a recommended TLV of 1.5 mg/m^3.[12] Based on Equation 2, the D_T estimate is 1.8×10^{-3} mg/kg/day.

TNB has not been intensively studied with the intent of finding no-effect level doses. The most applicable data available are from a rat feeding study by Fogleman, et al.;[35] the LD50 estimated for rats is 505 mg TNB/kg. Following the methods of Reference 2, the corresponding D_T of 5.8×10^{-3} mg/kg/day is estimated. This is a "method 1" calculation (see p. 11). Owing to the observation of microbial mutagenesis in an Ames battery of tests, a "method 2" calculation has also been included for TNB, giving a D_T of 5.8×10^{-5} mg/kg/day.

1,3-Dinitrobenzene has a recommended TLV[12] of 1 mg/m^3 although the information base is dated and of somewhat dubious reliability. Based on Equation 2, the D_T estimate is 1.2×10^{-3} mg/kg/day.

Diphenylamine reportedly[36] has a recommended ADI of 0.02 mg/kg/day. This value is used as the D_T estimate.

Aniline has a tentative recommended TLV of 10 mg/m^3.[37] Based on Equation 2, the D_T estimate is 1.2×10^{-2} mg/kg/day.

N,N-Dimethylaniline has a recommended TLV of 25 mg/m^3,[12] which appears to be founded on a tenuous data base and comparisons to aniline analogs. Through use of Equation 2, the D_T estimate is 3.0×10^{-2} mg/kg/day.

Nitrobenzene has a recommended TLV[12] of 1 ppm or 5.13 mg/m^3. Based on Equation 2, the D_T estimate is 6.2×10^{-3} mg/kg/day.

The D_T information presented above is summarized in Table 3.

TABLE 3. ESTIMATES OF ACCEPTABLE DAILY DOSES (D_T) FOR SUBSTANCES OF CONCERN AT ALABAMA ARMY AMMUNITION PLANT

Contaminant	Input Type of Information	Value	Reference	D_T mg/kg/day
TNT	90-day rat feeding study	1.4 mg/kg/day	31	1.4×10^{-3}[a] 1.4×10^{-5}[b]
DNT[c]	Water quality criteria	1.1 μg/L	10	3.2×10^{-5}
Tetryl	TLV	1.5 mg/m^3	12	1.8×10^{-3}
TNB	LD_{50}	505 mg/kg	35	5.8×10^{-3}[a] 5.8×10^{-5}[b]
1,3-Dinitrobenzene	TLV	1 mg/m^3	12	1.2×10^{-3}
Diphenylamine	Acceptable daily intake	0.02 mg/kg/day	36	2.0×10^{-2}
Aniline	TLV	10 mg/m^3	37	1.2×10^{-2}
N,N-Dimethylaniline	TLV	25 mg/m^3	12	3.0×10^{-2}
Nitrobenzene	TLV	1 ppm = (5.13 mg/m^3)	12	6.2×10^{-3}
Nitrocellulose[d]	--	--	--	1.2×10^{-3}
Lead[e]	Unofficial recommendations	--	34	8.0×10^{-3}

a. "Method 1;" see p. 11.
b. "Method 2," see p. 11.
c. Extrapolation methods used for mammalian oncogens indicate that the D_T would entail an increased risk of cancer of 10^{-5}.
d. Used for dust inhalation pathway only. Based on TLV for cotton linters.
e. Based on recommended value for ingestion with adjustment made for water and food sources not considered in the present study.

PARTITION COEFFICIENTS

In general, literature that provides these constants directly is rare. The methodology for estimating such constants is still in a formative stage. For substances other than nitrocellulose (for which ingestive pathways are not applicable) and lead (for which a more rigorous approach is used), reasonable estimation methods are employed.

K_{pa} (Plant to Animal Partition Coefficient)

The argument is that animals, when fed a constant concentration of a compound in their diet over an extended time period, bioconcentrate that substance to an asymptotic level. Organic substances appear predominantly in adipose (fatty) tissue. This approach is based on an analysis of long-term rat feeding studies with various chemicals.[38] In Reference 38, a correlation of bioconcentration factor (BF) with the water solubility of a compound was proposed for use in the absence of experimental data:

$$\log BF = 1.2 - 0.56 \log SS \tag{13}$$

where BF is the mg of substance per kg of adipose tissue/mg of substance per kg of food on a dry weight basis and SS is the water solubility in μg/L.

The authors anticipate that this approach and Equation 13 is applicable to other animals. It is similar to equations derived for the bioconcentration of organic compounds in fish. The approach is preferable to the presumption of complete compound retention, and simpler to apply than a "mass balance" approach. As a singular example, the polychlorobiphenyl mixture Arochlor 1254, a very water-insoluble and highly fat-soluble substance, was fed to milk cows by Fries, et al.[17] After 60 days of constant-level feeding, milk fat levels reached apparent asymptotic levels. The experimental results permit computation of a diet-milk fat BF, which agrees well with Equation 13.* While the behavior of one substance hardly validates a model, the agreement is encouraging.

In the absence of specific available data,

$$K_{pa} = BF \times FA \tag{14}$$

where FA is the fat fraction in the animal adipose tissue, or for dairy, in milk. Pollutant solubility data and computed values of BF are presented in Table 4.

* Compare 3.45 ± 0.95 (mean ± 1 S.D. for milk fat) to 3.94, the value estimated by use of Equation 13.

TABLE 4. SOLUBILITY DATA AND BIOCONCENTRATION FACTORS FOR SUBSTANCES OF CONCERN AT ALABAMA ARMY AMMUNITION PLANT

Substance	Solubility µg/L	Ref.	BF[a]
TNT	1.23×10^{5}	39	2.24×10^{-2} [b]
2,4-Dinitrotoluene	2.73×10^{5}	39	1.43×10^{-2} [b]
Tetryl	3.5×10^{4}	40	4.52×10^{-2}
TNB	3.2×10^{4}	39	4.76×10^{-2}
1,3-Dinitrobenzene	3.7×10^{5}	39	1.21×10^{-2}
Diphenylamine	3.6×10^{4}	36	4.45×10^{-2} [c]
Aniline	3.5×10^{7}	41	9.45×10^{-4} [c]
N,N-Dimethylaniline	1.6×10^{7}	41	1.46×10^{-3}
Nitrobenzene	1.78×10^{6}	38	3×10^{-2}

a. Nitrobenzene's BF is a reported value,[38] others are computed from Equation 13.

b. Based on excretion and metabolism considerations, a K_{pa} as low as 0.1 x the tabulated value may be applicable (see text).

c. Based on excretion and metabolism considerations, a K_{pa} as low as 0.5 x the tabulated value may be applicable (see text).

Four of the nine substances involved have been studied for metabolism and excretion. These studies involved a one-time dose (C-14 trace) followed by analysis for retained material after 24 hours. The proportions retained after 1 day (perhaps as metabolites) were:

1. TNT in mice, less than 10%.[42]

2. 2,4-Dinitrotoluene in rats, less than 10%.[43,44]

3. Aniline in sheep, about 50%.[41]

4. Diphenylamine in rats, about 50%.[36]

Fairly high rates of elimination, along with metabolic transformations, if applicable to cows, swine and deer, would argue for inclusion of fractional adjustments in K_{pa}. Soil bacteria ingested by ruminants (cows and deer) could enhance this process. Moreover, metabolites are generally more polar and less fat-soluble than, and should accumulate less than, their precursors. On the other hand, the extent of the removal/metabolism processes in the studies cited[38] were not established. Exclusion of fractional adjustments for elimination of metabolites would lead to lower SPPPLV estimates. Thus, their exclusion from Equation 14 is a conservative assumption.

K_{sp} (Soil to Plant Partition Coefficient)

No correlations for organic substances exist. In the absence of participation in plant metabolism, organic uptake is probably positively correlated with water solubility.[45] A few studies illustrate some extreme situations.

In one study, Fries[46] noted that the increase of DDT concentration in turnip greens, tobacco leaves and peanut forage ranged from 0.06 to 0.09 ppm for each ppm increase of DDT in soil. Water solubility of DDT is in the order of 1 to 2 µg/L. In contrast, radiolabeled para-chlorophenyl methyl sulfone, a compound with solubility in the range of 10 g/L,* was added to a sandy loam of 0.8% organic content for plant tests.[47] Plant uptakes corresponding to K_{sp} of values 40 for plant tops and 7 for roots were reported.

The substances considered here (except nitrocellulose and lead) are intermediate in solubility betwen DDT and para-chlorophenyl methyl sulfone. A default K_{sp} of 1.0 is used for such substances.

K_{ad} (Animal Fat to Butterfat Partition Coefficient)

K_{ad} is assumed equal to 1.44 for organic substances. The value 1.44 is based on the study by Fries, et al.,[17] and represents the ratio of Arochlor 1254 found in butterfat to its concentration in body fat. Other organic substances may have K_{ad} values closer to 1.0. Thus, the value used here is somewhat safe-sided.

SPPPLV COMPUTATIONS FOR ORGANIC SUBSTANCES

Equation 9 is applicable to Pathway 1. Data to evaluate this equation are: BWA = 70 KG; VC = 0.459 kg x 0.16 kg dry weight per kg wet weight or 0.0735 kg; and K_{sp} = 1. The resulting expression is:

$$C_{s1} = 953 \times D_T \tag{15}$$

Equation 10 is applicable to Pathway 2. Equation 14 is incorporated into Equation 10 to provide an expression in terms of BF:

* There are no direct solubility measurements for this obscure compound. Dr. Clarence W.R. Wade of this Laboratory has determined its octanol/water partition coefficient to be 16.2 (unpublished data). Equations relating this coefficient to solubility[48] provide estimates of the order cited above.

$$C_{s2} = BWA \times D_T/(MC \times K_{sp} \times BF \times FA) \quad (16)$$

For beef and pork, MC = 0.29 kg/day. For beef, FA = 0.3 and:

$$C_{s2} = 804 \times D_T/BF \quad (17)$$

For pork, FA = 0.45 and:

$$C_{s2} = 536 \times D_T/BF \quad (18)$$

Venison is assumed to incidentally supplement the meat diet. C_{s2} for deer is based on assumed consumption patterns (44 kg of venison from one animal per year per family), FA = 0.20, and a factor of 0.1 to account for browsing patterns that include both contaminated and non-contaminated areas. The numerical evaluation is:

$$C_{s2} = [(70 \times 365)/(0.1 \times 0.2 \times \{44/4\})] \times (D_T/BF)$$

or $$C_{s2} = 116140 \times D_T/BF \quad (19)$$

Equation 11 (with Equation 14 substituted) is applied for Pathway 3. The new variables here are DC = 0.756 kg/day; FA = 0.0391; and K_{ad} = 1.44. The numerical result is:

$$C_{s4} = 1645 \times D_T/BF \quad (20)$$

Equation 12 is applied for Pathway 4. Here, BWC = 12 kg and SC = 100 mg/day soil or 10^{-4} kg/day soil. Thus:

$$C_{s4} = 1.2 \times 10^{+5} \times D_T \quad (21)$$

The formulation for pathway 5 is rather model-specific. The model used here includes the following features:

1. With the exception of 2,4-dinitrotoluene, the D_T values derived in section on SPPPLV Computations for Organic Substances have incorporated into them safety-factors such as was used in Equation 1. A less stringent margin of safety can be accepted for application to the working population, as the people involved are a robust component of the general population. Thus, for this pathway, $D_T' = 10 \times D_T$ is employed. For 2,4-dinitrotoluene, relaxation of D_T is not appropriate, and $D_T' = D_T$.

2. When a worker is exposed to dust, he may be exposed to as much as 10 mg soil/m^3 air concentration. This specific value is the TLV for nuisance dust in workroom air.[12] Such a concentration of dust would be considered rather extreme in out-of-doors surroundings.

3. A typical worker has a 5-day, 8-hour-per-day, week and works 225 days yearly.

4. The worker is exposed to dust only when the ground is fairly dry and only when the wind is of low enough velocity that the dust is not rapidly dispersed or when dust is blown towards the worker. These favorable dust-cloud formation factors are anticipated to jointly occur during 40% of working hours.

The daily acceptable intake for workers is D_T' x BWA. On a yearly basis, this is 365 x D_T' x BWA or 25550 x D_T'. In a working year, a worker can inhale 10 mg dust/m^3 x 225 days/year x 0.4 x 12.1 m^3 air/day or 0.0109 kg dust/year. By PPLV definition:

$$C_{s5} = 25550 \times D_T'/0.0109 = 2.34 \times 10^{+6} \times D_T' \qquad (22)$$

where C_{s5} is this pathway PPLV in mg pollutant/kg dry soil. For organic substances other than 2,4-dinitrotoluene,*

$$C_{s5} = 2.34 \times 10^{+7} \times D_T \qquad (23)$$

and for 2,4-dinitrotoluene,

$$C_{s5} = 2.34 \times 10^{+6} \times D_T \qquad (24)$$

The SPPPLVs shown in Table 5 were computed with these equations by the use of the D_T information in Table 3 and the BF estimates in Table 4. The results appear in Table 5.

PATHWAY COMPUTATIONS FOR LEAD

As discussed in the Special Cases Section, lead presents a special situation, particularly for ingestion-related pathways. The PPLV derivation from SPPPLV estimates, Equation 8, is not valid for lead, since pathways not specifically addressed in a scenario also provide lead to the diet. The problem becomes one of restricting total lead intake to less than a specific value (535 μg/day for adults and 95 μg/day for a 2-year old child). Some of these intakes are associated with contaminated soil, some are not. In this section, the pathway-based estimates for both situations are derived. The presentation of pathways is not in numerical consecutive order.

Pathway 5

The action level of 30 μg Pb/m^3 in workroom air should not cause untoward effects to most exposed workers, although there is a remote probability that clinically-detectable symptoms could occur in highly sensitive individuals.[49] For this level to be maintained by airborne dust of 10 mg soil/m^3 air concentration, a 3,000 mg Pb/kg soil content is required. Taking into consideration the pathway model assumptions of workdays and weather conditions favorable to airborne dust, a 8,530 mg Pb/kg soil concentration is computed. The authors recommend adoption of the more restrictive 3,000 mg Pb/kg soil value as this SPPPLV.

*Equation 23 can be used for nitrocellulose also. First, the assumed nitrocellulose TLV of 1 mg/m^3 is used in Equation 2.

TABLE 5. SPPPLVs (mg/kg) FOR ORGANIC SUBSTANCES OF CONCERN AT ALABAMA ARMY AMMUNITION PLANT

Substance	Pathway 1	Pathway 2			Pathway 3	Pathway 4	Pathway 5
	Vegetable Consumption	Beef	Pork Consumption	Venison	Dairy Consumption	Soil Ingestion	Dust Inhalation
TNT--"Method 1"[a]	1.33	50.2	33.5	7260	103	168	33200
"Method 2"[a]	0.0133	0.502	0.335	72.6	1.03	1.68	332
2,4-Dinitrotoluene	0.0305	1.80	1.20	260	3.68	3.84	76
Tetryl	1.72	32.0	21.3	4620	65.5	2.6	42700
TNB--"Method 1"[a]	5.53	98.0	65.3	14200	200.0	696	137000
"Method 2"[a]	0.0553	0.98	0.653	142	2.0	6.96	1370
1,3-Dinitrobenzene	1.14	79.7	53.2	11500	163.0	144	28400
Diphenylamine	19.1	361.0	241.0	52200	740.0	2400	474000
Aniline	11.4	10200.0	6810.0	1470000	20900.0	1440	284000
N,N-dimethylaniline	28.6	16500.0	11000.0	2390000	33800.0	3600	711000
Nitrobenzene	5.91	166.0	111.0	24000	340.0	744	147000
Nitrocellulose	N/A	N/A	N/A	N/A	N/A	N/A	28400

a. See p. 11 for explanation of "Method 1" and "Method 2."

Pathway 1

The complication here is illustrated by a study by Chaney, et al.[50] The lead content of soils in 50 gardens in Baltimore, MD, and foliar lead levels of collard greens grown in these gardens were determined. The foliar levels were weakly, if at all, related to soil-lead content, which ranged from 46 to 10900 mg Pb/kg. A mean foliar content of 6.3 mg Pb/kg (dry basis) was estimated.

Pathway 1 probably does not, on the basis of human effects, provide a basis for a SPPPLV. However, regardless of the geographical source of vegetables, their consumption involves ingestion of lead. Kolbye, et al.[16] reported on lead in typical diets. One complicating factor in the analysis of lead content was the sensitivity of the lead assay methods; samples often assayed as "trace" or "not detectable." Based on reasonable assumptions of what such results imply, they estimated that the vegetables in a daily diet contain 65 μg of lead. A similar analysis for 2-year old children provides a 25 μg/day estimate.

Pathway 3

Pathway 3 requires an unusual approach. Lead can be toxic to cattle; and this would place an upper limit on soil-lead content. Dairy cows graze on pastures; the lead content of the plant matter is probably insensitive to soil-lead content. Soil is consumed in the grazing process, and may provide a significant portion of the lead in dairy products.

Botts has reviewed livestock lead toxicity information.[51] He estimates that an ingestion rate of 2 mg Pb/kg animal weight/day is safe for cattle. The typical lead content for pasture plant material is not well documented, but the 6.3 mg Pb/kg value for collard greens[50] may be somewhat high-sided. Here, a 5 mg Pb/kg (dry weight) value is used. Based on a 542 kg animal, a cow may safely ingest 1,084 mg Pb/day. At representative pasture consumption (16.5 kg/day) and soil intakes (0.72 kg/day), the limiting lead content in soil on the basis of potential harm to cattle is:

$$(1084 - (5 \times 16.5))/0.72 = 1390 \text{ mg Pb/kg} \tag{25}$$

Note that this computation is relatively insensitive to plant lead content.

A data-fitting model is proposed for relating lead-milk content to that of soil. The model is:

$$L(\text{milk}) = A1 + (A2 \times LS) \tag{26}$$

where L(milk) is the milk content in μg Pb/kg; A1 accounts for lead intake from ingested plant matter (assumed not related to lead-soil content) and A2 accounts for proportional intake from ingested soil.

Typical milk-lead levels have been reported by Lynch, et al.[52] as 49 ppb (μg/kg) and 40 μg/L by Mitchell and Aldous.[53] The latter figure was based on a survey of 270 samples. A representative value of 45 μg/kg is assumed, and is assumed correlatable to a soil-lead content of 30 mg/kg (that occurring in background soil samples in the Alabama Army Ammunition Plant area). A proportionality factor B is first computed:

$$45\ \mu g/kg = B \times 16.5\ kg/day \times 5\ mg\ Pb/kg + B \times 0.72\ kg/day \times 30\ mg/kg \qquad (27)$$

from which B = 0.433. Equation 26 is then written as

$$L(milk) = 35 + 0.312 \times LS \qquad (28)$$

Further use of this equation (after multiplying by the daily human consumption factor) is made in Table 6.

From the typical milk-lead level above, a typical daily lead intake from dairy products for adults and 2-year old children can be computed. For adults, the intake is 0.756 kg/day x 45 μg Pb/kg milk = 34 μg Pb/day. For the 2-year old child, the intake is 0.56 kg/day x 45 μg Pb/kg milk = 25 μg Pb/day.

TABLE 6. DAILY LEAD INTAKES FROM DIET COMPONENTS OF CONCERN

Diet Component	Person	Lead Intake from Specified Diet Component, μg Pb/day: Uncontaminated Land	Lead Intake from Specified Diet Component, μg Pb/day: Contaminated Land (LS = mg Pb/kg Soil)
Vegetables	Adult	65	65
	2-year old	25	25
Beef	Adult	29	$19.3 + 0.168 \times LS$
	2-year old	11	$9.0 + 0.079 \times LS$
Pork	Adult	22.1	22.1
	2-year old	10.3	10.3
Venison[a]	Adult	9.3	$8.9 + 6.27 \times 10^{-3} \times LS$
	2-year old	4.2	$4.1 + 2.85 \times 10^{-3} \times LS$
Dairy	Adult	34	$26.5 + 0.236 \times LS$
	2-year old	25	$19.6 + 0.175 \times LS$
Soil	2-year old	3.0	$0.1 \times LS$

a. Based on incidental use in diet, adult's nominal daily consumption of 0.033 kg/day; 2-year old, 0.015 kg/day.

Pathway 2

Estimation of the lead content in meat involves a model similar to that of Equation 26. As a complication, lead is known to accumulate preferably in bone, liver, and kidney.[51,54]

A cow will consume both pasture and soil, which causes a daily lead intake of:

$$LC = 82.5 + 0.72 \times LS \tag{29}$$

where LC is mg Pb/day intake, 82.5 is the mg Pb/day from plant material and LS is in mg Pb/kg soil. Cattle, as ruminants, have a digestive system that absorbs only 1 to 2% of ingested lead.[55] Assuming an intermediate value of 1.5% and 530 days of a 2-year lifetime on pasture,* the accumulated lead level is:

$$AL = 1.5 \times 10^{-2} \times 530 \times LC = 656 + 5.72 \times LS \tag{30}$$

where AL is the number of milligrams of lead accumulated in a lifetime.

The concentration in bone, kidney, and liver is as much as 100 times that in plasma or muscle, which, with fat, comprises beef.[50] A somewhat more conservative factor of 75 is used here. Typical weights of these three organs for cattle are available;[21,56] the total weight involved is 88 kg. Unlike organic compounds, lead salts are water-soluble, and probably do not accumulate at all in body fat; it is assumed that body fat accumulates no lead. After deductions for lead-preferring organs and fat, 318 kg of other weight remains. A mass balance on lead-containing tissues and organs is:

$$AL = 75 \times (XM) \times 88 \text{ kg} + 318 \text{ kg} \times (XM) = 6918 \text{ (XM)} \tag{31}$$

where XM is the lead content in muscle in mg/kg. The lead content in muscle as a function of lead-soil content can be computed by elimination of AL between Equations 30 and 31, namely:

$$XM = 0.0948 + 8.27 \times 10^{-4} \times LS \tag{32}$$

Since muscle comprises 70% of beef and non-lead containing fat the remainder, the lead-meat content is (with a conversion of units):

$$L(\text{Beef}) = 66.4 + 0.58 \times LS \tag{33}$$

where L(Beef) is in μg/kg.

For a non-contaminated soil with a background of perhaps 30 mg Pb/kg, the daily intake of lead from beef for adults would be 83.8 μg/kg x 0.290 kg/day or 24 μg/day; for 2-year old children, 83.8 x 0.136 = 11 μg/day.

Pork-lead content involves a somewhat simpler approach, since the assumed process of corn-feeding leads to little, if any, soil ingestion. Lead would

* Cattle spend the first 7 months of life progressing from 100% milk dependency to a fully weaned condition.[20] They will ingest some lead from mother's milk, pasture and soil in this period. On the other hand, a 7-month calf has considerably less weight than the "typical" animal considered. A 530-day pasture life appears a reasonable compromise for these offsetting factors.

be derived from corn, which is assumed, as in Pathway 3, to have a 5 mg Pb/kg lead content. The corn consumed in a pig's lifetime is 410 kg; the corn is about 85% solids. Hence the ingested lead is about 410 kg x 5 mg/kg x 0.85 = 1742 mg. The digestive system of swine resembles that of man;[50] perhaps 10% of the ingested lead is absorbed or 174.2 mg. Lead-preferring organs in swine are assumed to involve 15% of an animal's weight or 16 kg, while the remaining non-fat weight is 0.55 (109 kg - 16 kg) or 51 kg. Analogously to Equation 31,

$$174.2 \text{ mg} = 75 \times 16 \text{ kg} \times (XM) + 51 \text{ kg} \times (XM) \qquad (34)$$

or XM = 139 μg Pb/kg. Since pork is assumed 45% fat, the lead content in pork is L(pork) = 0.55 x 139 = 76.4 μg/kg. For adults, use of pork as the meat source in a diet would involve a daily lead intake of 22.1 μg/day; for the 2-year old child, 10.3 μg/day.

As a check on the realism of the beef and pork estimates, one may refer to the Kolbye, et al. study, which predicts a 20 μg Pb/day intake from meat, poultry and fish.[16] The model presented, when evaluated at a 30 mg Pb/kg soil level for a meat diet of 2:1 beef to pork predicts 26.4 μg Pb/day in the diet.

Model data on deer are not available; only a rough approximation is presented. This approximation must account for lead intake from browsing on land with background lead content as well as contaminated land. Since deer are ruminants, the treatment for cattle will be generally applicable. A deer is assumed to have 15% of the weight of a cow, and to consume plants and soil in scale similar to cattle. Thus, Equation 29 can be scaled to deer:

$$LD = 12.38 + 0.108 \times LS \qquad (35)$$

where LD is the daily lead ingestion by deer. A deer is assumed to graze 90% of his diet on uncontaminated land (30 mg Pb/kg) and 10% on contaminated land. Equation 35 can be modified to account for this by considering these land categories separately:

$$LD = 0.9 \times (12.38 + 0.0108 \times 30) + 0.1 \times (12.38 \times 0.0108 \times LS) \qquad (36a)$$

or

$$LD = 15.3 + 0.0108 \times LS \qquad (36b)$$

Deer are assumed to absorb 1.5% of ingested lead, and to have an average 4-year lifetime. Analogously to Equation 30:

$$AL = (1.5 \times 10^{-2}) \times (4 \times 365) \times LD = 335 + 0.236 \times LS \qquad (37)$$

A deer is also assumed to have 15% of its weight in lead-preferring organs or 12.5 kg, and of the remaining weight, 20% fat. Thus, analogously to Equation 31,

$$AL = 75 \times (XM) \times 12.5 \text{ kg} + 56.4 \text{ kg} \times (XM) = 994 \times (XM) \qquad (38)$$

Analogously to Equation 33, L(venison) in μg Pb/kg is:

$$L(\text{venison}) = 270 + 0.190 \times LS \qquad (39)$$

Pathway 4

The lead absorption in μg/day as a result of soil ingestion is simply $0.1 \times LS$.

PPLV COMPUTATIONS

Calculation of the PPLVs for the nine organic substances subject to the entire PPLV computational procedure involves use of the SPPPLV values from Table 5 and Equation 8. If one SPPPLV is lower than others considered by a factor of 10 or so, Equation 8 may be approximated by

$$C_{sf} = (C_{sfi}) \text{ lowest } \approx \text{ minimum } C_{si} \tag{40}$$

without excessive loss of accuracy.

The PPLV from ingested lead pathways involves a summation of lead intakes of dietary components. These have been derived in the section on Pathway Computations for Lead. For convenience, they are summarized in Table 6, with adjustments made for daily consumption rates. The summations, based on arguments in the section on Special Cases, should not exceed 535 μg Pb/day for an adult and 95 μg Pb/day for a 2-year old child.

SUBSISTENCE FARMING SCENARIO

An examination of Table 5 shows that vegetable ingestion leads to the lowest SPPPLVs, and that the value associated with this pathway for a given soil contaminant is less than one-tenth of any others. Thus, the vegetable pathway results of Table 5 would be recommended as PPLV values for this scenario.

An examination of Table 6 indicates that the beef-based diet would lead to lower PPLV-estimates than a pork-based diet. Hence, the beef-based diet will be used for subsequent computations. For adults, the lead PPLV is the soil-lead concentration which will, based on vegetable, dairy, and meat consumption, provide 535 μg Pb/day. Mathematically, this is:

$$535 = 110.8 + 0.404 \times LS \tag{41}$$

whereupon, LS = 1050 mg Pb/kg soil.

For children, the analog to Equation 41 must include provision for soil ingestion. Hence:

$$95 = 53.6 + 0.354 \times LS \tag{42}$$

From which LS = 117 mg Pb/kg soil. Thus, the PPLV for lead is child-determined for this scenario, and would be estimated at 117 mg Pb/kg soil.

RESIDENTIAL HOUSING SCENARIO

An examination of Table 5 shows again that vegetable ingestion is PPLV-determining, and that the vegetable results can be directly used for recommended PPLV value for the nine organic compounds.

An examination of Table 6 shows that child considerations will determine the most restrictive PPLV, and the beef-meat diet is the most restrictive option of alternatives in Pathway 2. The mathematical relation for LS is:

$$95 = 61.22 + 0.1 \times LS \qquad (43)$$

or LS = 338 mg Pb/day.

APARTMENT HOUSING SCENARIO

In this scenario, only pathway 4 is involved. The values for this pathway in Table 5 can be used directly for PPLV recommendations.

The lead PPLV for this scenario is the same as computed in the previous section, as both scenarios are based on diets insensitive to lead-soil content.

INDUSTRIAL SCENARIO

Only inhalation of dust (Pathway 5) is of concern here. The values in Table 5 for this pathway would be recommended for the organic compounds. A value of 3,000 mg Pb/kg soil was developed in the section on Pathway Computations for Lead.

HUNTING SCENARIO

Only the ingestion of venison (Pathway 2 variant) is of concern here. The values for this case in Table 5 would be recommended for the organic substances.

The lead PPLV is again child-determined, and the applicable equation involves non-contaminated land sources of vegetables, beef, dairy products, the incidental ingestion of background-level leaded soil, along with the consumption of venison. The mathematical relation is:

$$95 = 25 + 11.37 + 24.85 + 3.0 + 4.1 + 2.85 \times 10^{-3} \times LS \qquad (44)$$

or

$$LS = 9360 \text{ mg Pb/kg soil.}$$

DISCUSSION

For convenience, the PPLV estimates for the various scenarios are consolidated in Table 7. The SPPPLV computations show that Pathway 1 (vegetable consumption), when a relevant pathway, should be PPLV-determining. In particular, 2,4-dinitrotoluene contamination is expected to present the most serious problem, although other organic substances have been detected in soils

at Alabama Army Ammunition Plant at levels exceeding PPLV estimates. The 2,4-dinitrotoluene results are lowest, primarily because of the low D_T value assigned by reason of the criteria of carcinogenic effect. Nitrocellulose has a PPLV only for the industrial use scenario. The 28,000 mg/kg estimate (2.8% of soil) is well in excess of any known contamination at the plant.

The rather high PPLVs calculated for some pathways (10,000 mg/kg = 1% soil content by weight) would suggest that these pathways are relatively inefficient methods of challenging a human with these substances. For venison ingestion, the high values reflect the two assumptions of low nominal daily intake and of unrestricted browsing habits.

The high PPLV values in the industrial scenario could suggest consideration of direct vapor inhalation as an alternative pathway. For example, aniline has a 1 mm Hg vapor pressure at 35 ^oC.[57] Conceivably, pure aniline could create a saturated air mass with an aniline content of 4,800 mg/m^3, far in excess of a TLV. It is doubtful whether outdoor conditions, except in most unusual circumstances, could be conducive to maintaining this high an aniline concentration in a significant air volume. Given the 35 years from the last introduction of aniline to soil, the bulk of such vapor-generated material would have dissipated. Finally, at low concentrations, the compound would be absorbed in soil organic matter, and would exhibit a lower vapor pressure than that expected of pure compound.

[redacted], the hunting and [redacted]. A comparison of lead PPLV values to numerical lead levels determined by surveys (see Table 1) indicates a similar state of affairs. However, [redacted]. Environmental action on elemental lead would cause the formation of salts that are the major lead-bearing substances of concern in SPPPLV computations.

One specific land-use scenario that was of interest to USATHAMA was timber harvesting. Timber harvesting involves intense, but short-lived activity in a given area. Moreover, decades may pass before a harvested area has trees again capable of harvesting. The scenario presented appears a reasonable representation of timber harvesting when it occurs. Given the transitory nature of the operation in a given area, PPLV estimates less restrictive than any of those presented in Table 7 would apply, and probably would indicate no need for major land renovation efforts.

The authors would expect any land renovation efforts to entail physical removal of contaminated soil and its replacement with non-contaminated soil. The requirement for removing suspected contaminated soil of 69000 m^3 volume (see section on Site Background) is not an insurmountable task; this is the equivalent of excavating an acre plot of land to a 56-foot depth. Two general strategies could be considered: to remove "hot-spots" with extreme contamination if indeed the contamination pattern indicated this was the situation; or to "remove it all" if the cost of detecting "hot-spots" should be excessive or if the land is uncontrolled as to further use. The authors do not have sufficient information available to suggest a specific approach.

TABLE 7. PPLVs (mg/kg) FOR SOIL ACCORDING TO SELECTED LAND USE SCENARIOS AT ALABAMA ARMY AMMUNITION PLANT

Substance	Subsistance Farming	Residential Housing	Apartment Housing	[redacted]	Hunting
TNT--"Method 1"[a]	1.3[b]	1.3[b]	168	33200	7260
"Method 2"[a]	0.013	0.013	1.68	332	72.6
2,4-Dinitrotoluene	0.03[c]	0.03[c]	3.6[c]	76	260
Tetryl	1.7[d]	1.7[d]	216	42700	4620
TNB--"Method 1"[a]	5.5	5.5	696	137000	14200
"Method 2"[a]	0.055	0.055	6.96	1370	142
1,3-Dinitrobenzene	1.1	1.1	144	28400	11500
Diphenylamine	19	19	2400	474000	52200
Aniline	11	11	1440	284000	1470000[e]
N,N-Dimethylaniline	29	29	3600	711000	2390000[e]
Nitrobenzene	5.9	5.9	744	147000	24000
Nitrocellulose	N/A	N/A	N/A	28400	N/A
Lead	117[f]	338[f]	338[f]	3000	9360

a. See p. 11 for explanation of "Method 1" and "Method 2."
b. PPLV exceeded by some Area 16 samples (see Table 1).
c. PPLV exceeded in one or more areas (see Table 1).
d. PPLV exceeded in Area 16 (see Table 1).
e. The physical significance of such high values is discussed in the text.
f. PPLV exceeded in several areas (see Table 1).

A decision to allow apartment residential use of land would involve, for the most part, considerations based on lead levels, although area 20 has 2,4-dinitrotoluene contents that exceed this scenario's PPLV. In this case, one may wish to reconsider assumptions made in arriving at Pathway 4 SPPPLVs, particularly whether "pica" consumption is to be neglected. This would be most important in a "hot spot" removal strategy, and relatively unimportant in a "remove it all" strategy.

The situation is more straightforward for the subsistence farming and residential housing scenarios. Here, vegetable consumption is the dominant pathway. It appears that a "remove it all" approach would be needed for either scenario.

RECOMMENDATIONS

The reader is advised to reread the Report Organization and Caveats Section of the Introduction. While the authors have tried to apply reasonable approaches to the determination of PPLVs, most of them rest on assumptions that cannot be readily validated. The PPLVs presented in Table 7 are scenario-specific and based on the assumptions presented concerning scenarios and their component pathways. Should different scenarios arise, they would have to be then addressed. For example, if horse-raising were a scenario, it would be prudent to consider the toxicity of the contaminants to horses, especially lead. If pica in children were to be safeguarded against, a soil ingestion value representative of this consumption would be introduced into the computational framework.

The treatment of partition coefficients is highly rudimentary, particularly that of K_{sp}, i.e., uptake of contaminants by plants. Establishment of such factors from meaningful correlations with the physicochemical properties of pollutants would be of considerable help in properly defining the potential for exposure.

As a stop-gap, an actual test of pasture and vegetable content in highly contaminated areas of the Alabama Army Ammunition Plant would be useful in validating the computations. Of most interest are areas contaminated with 2,4-dinitrotoluene, tetryl, TNT and TNB. Should plant data indicate far less uptake than that assumed by $K_{sp} = 1$, the PPLV values corresponding to vegetable consumption would be less restrictive. Moreover, as shown in Appendix A, this assumption directly affects the importance of soil ingestion as a source of organic pollutant intake for livestock and dairy animals. The equations concerning lead intake (Equations 28, 33, and 39) are sensitive to the assumed lead content in vegetable or forage crop matter. If these contents were lower than the 5 mg/kg value used herein, the resulting PPLVs for lead for the subsistence farming and the residential housing scenarios could be adjusted.

The nitrocellulose level in soil appears to require restriction only in the industrial scenario, and that at a 28,000 mg/kg level. Other considerations may be involved should other scenarios be actively pursued, such as the potential for ignition at a 2.8% soil content. This could easily be ascertained.

REFERENCES

1. Rosenblatt, D.H., J.C. Dacre, and D.R. Cogley. 1980. An environmental fate model leading to preliminary pollutant limit values for humnan health effects. Technical Report 8005, AD B049917L. U.S. Army Medical Bioengineering Research and Development Laboratory, Fort Detrick, Frederick, MD.

2. Dacre, J.C., D.H. Rosenblatt, and D.R. Cogley. 1980. Preliminary pollutant limit values for human health effects. Environ. Sci Technol. 14:778-784.

3. Records Evaluation Report No. 130. 1978. Installation assessment of Alabama Army Ammunition Plant, Childersburg, AL. Department of the Army Office of the Project Manager for Chemical Demililitarization and Installation Restoration, Aberdeen Proving Ground, MD.

4. Zarzycki, J. 1980. Personal communication. U.S. Army Toxic and Hazardous Materiels Agency, Aberdeen Proving Ground, Aberdeen, MD.

5. Mizell, D. and M.A. Kiern. 1980. Personal communication. Environmental Science and Engineering, Inc., South St. Louis, MO.

6. Nemeth, G. 1980. Personal communication. U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Aberdeen, MD.

7. Torrisi, S. 1981. Personal communication. U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Aberdeen, MD.

8. U.S. Army Toxic and Hazardous Materials Agency. 1980. Report of contamination at Alabama Army Ammunition Plant (AAPII-GSALB.1). Draft.

9. Rosenblatt, D.H., M.J. Small, and J.J. Barkley, Jr. 1973. Munitions production products of potential concern as waterborne pollutants - Phase I. Technical Report 73-07, AD 912752. U.S. Army Medical Environmental Engineering Research Unit, Edgewood Arsenal, MD.

10. Water quality criteria documents; availability. Federal Register 45(231):79318-79379.

11. Occupational safety and health administration tentative list of carcinogens for proposed generic policy. 1978. In Chemical Regulation Reporter, Current Reports 2:(16)638-655.

12. Documentation of the threshold limit values for substances in workroom air. 1974.* American Conference of Governmental Industrial Hygienists, Cincinnati, OH, Second Printing, Third Edition.

* Document is revised periodically. Cited reference used in study.

13. U.S. Department of Agriculture. 1975.* Agricultural statistics, U.S. Government Printing Office, Washington, DC.

14. Committee on Lead in the Human Environment. 1980. Lead in the human environment, National Academy Press, National Academy of Sciences, Washington, DC.

15. Mahaffey, R.R. 1977. Quantities of lead producing health effects in humans: Sources and bioavailability. Environ. Health Perspectives 19:282-295.

16. Kolbye, A.C., Jr., K.R. Mahaffey, J.A. Fiorino, P.C. Corneliussen, and C.F. Jelinek. 1974. Food exposures to lead. Environ. Health Perspectives 7:65-74.

17. Fries, G.F., G.S. Marrow, Jr., and C.H. Gordon. 1973. Long-term studies of residue retention and excretion by cows fed a polychlorinated biphenyl (Arochlor 1254). J. Agric. Food Chem. 21:117-120.

18. Yeager, J.H. 1980. Personal communication. Professor of Agricultural Economics and Rural Sociology, Auburn, AL.

19. Poole, J. 1980. Personal communication. Maryland Agricultural Extension Service, Frederick, MD.

20. Juergenson, E.M. 1974. Approval practices in beef cattle production. Interstate Printers and Publishers, Inc., Danville, IL.

21. Ritchie, H.D. Not Dated. From steer to steak. Cooperative Extension Service Animal Science Fact Sheet 105, Dept. of Animal Science, University of Maryland, College Park, MD.

22. Huffman, D. 1980. Personal Communication. Auburn University, Auburn, AL.

23. Smith, P.M. 1980. Personal communication. Alabama Agricultural Extension Service, Auburn, AL.

24. Hartsock, T. 1980. Personal communication. University of Maryland, College Park, MD.

25. Rich, L.G. 1973. Environmental systems engineering. McGraw-Hill, Inc., New York, NY.

26. Kintz, J. 1980. Personal communication. Real Estate Evaluation Branch, Region III (Baltimore), Department of Housing and Urban Development, Baltimore, MD.

27. Biology Data Book. 1972. Altman, P.L. and D.S. Dittmer, eds. Federation of American Societies for Experimental Biology, Bethesda, MD.

28. Morris, L.L. April 9, 1980. Dirt could be dangerous - agriculture scientists warn of lead in Baltimore. The Sun, p. B-3, Baltimore, MD.

29. Healy, W.B. 1968. Ingestion of soil by dairy cows. N.Z.J. Agric. Res. 11:487-499.

30. Watt, B.K. and A.L. Merrill. 1975. Composition of foods (Agriculture Handbook No. 8). U.S. Department of Agriculture, Government Printing Office, Washington, DC.

31. Draft of Recommended Interim Environmental Criteria for Six Munitions Compounds, prepared by Dr. Jack C. Dacre, circa August 1980.

32. Preventative Medicine and Public Health. 1973. P.E. Sartwell, ed. 10th Edition, Appleton-Century-Crafts, New York, NY.

33. Safe Water Drinking Committee. 1977. Drinking water and health. National Academy Press, National Academy of Sciences, Wasington, DC.

34. Mahaffey, R.R. 1977. Relation between quantities of lead ingested and health effects of lead in humans. Pediatrics 59:448-456.

34a. Dilley, J.V., C.A. Tyson, and G.W. Newell. 1979. Mammalian toxicological evaluation of TNT wastewaters. Vol. III. Acute and subacute mammalian toxicity of condensate water. Final Report, AD A080957. SRI International, Menlo Park, CA. DAMD 17-76-C-6050.

35. Folgeman, R.W., J.R. Elsea, O.E. Paynter, and W. Kundzins. 1955. Toxicity of trinitrobenzene-aniline complex, a rodent repellent. Agric. Food Chem. 3(11):936-939.

36. Berkowitz, J.B. 1979. Literature review -- problem definition studies on selected chemicals. Monthly Progress Report #23, Contract No. DAMD 17-77-C-7037, Arthur D. Little, Inc., Cambridge, MA.

37. Threshold limit values for chemical substances in workroom air adopted by ACGIH for 1979. 1979. American Conference of Governmental Industrial Hygienists, Cincinnato, OH.

38. Geyer, H., A.G. Kraus, W. Klein, E. Richter, and F. Korte. 1980. Relationship between water solubility and bioaccumulation potential of organic chemicals in rats. Chemosphere 9:277-291.

39. Spanggord, R.J., T. Mill, T.-W. Chou, W.R. Mabey, J.H. Smith, and S. Lee. 1980. Environmental fate studies on certain munition wastewater constituents. Final Report, Phase I - Literature Review, Contract No. DAMD 17-78-C-8081, SRI International, Menlo Park, CA.

40. Burlinson, N.E. 1980. Personal Communication. U.S. Naval Surface Weapons Center, White Oak Laboratory.

41. Berkowitz, J.B. 1979. Literature review - problem definition studies on selected chemicals. Monthly Progress Report #26, Contract No. 20, Contract No. DAMD 17-77-C-7037, Arthur D. Little, Inc., Cambridge, MA.

42. El-hawari, A.M., J.R. Hodgson, J.M. Winston, M.D. Sawyer, M. Hainje, and C.-C. Lee. 1979. Evaluation of difference in mammalian metabolism of trinitrotoluene (TNT) as a function of route of administration and carcxinogenic testing. Draft Final Report, Contract No. DAMD 17-76-C-6066, Midwest Research Institute, Kansas City, MD.

43. Ellis, H.V., J.H. Hagensen, J.R. Hodgson, J.L. Minor, C.-B. Hong, E.R. Ellis, J.D. Girvin, D.O. Helton, B.L. Herndon, and C.-C. Lee. 1979. Mammalian toxicity of munitions compounds, Phase III: Effects of life-time exposure. Part I: 2,4-dinitrotoluene. Final Report #7, Contract No. DAMD 17-74-C-4073, Midwest Research Institute, Kansas City, MO.

44. Lee, C.-C, J.V. Dilley, J.R. Hodgson, D.O. Helton, W.J. Wiegand, D.N. Roberts, B.S. Andersen, L.M. Halfpap, L.D. Kurtz, and N. West. 1975. Mammalian toxicity of munition compounds: Phase I. Acute oral toxicity primary skin and eye irritation, dermal sensitization, and disposition and metabolism. Final Report #1, Contract No. DAMD 17-74-C-4073, Midwest Research Institute, Kansas City, MO.

45. Craker, L. 1980. Personal communication. University of Massachusetts, Worcester, MA.

46. Fries, G.F. 1980. An assessment of potential residues in animal products from application of sewage sludge containing polychlorinated biphenyls to agricultural land. Paper presented at the Symposium on Evaluation of Health Risks Associated with Animal Feeding and/or Land Application of Municipal Sludge, Tampa, Florida.

47. Guenzi, W.D., W.E. Beard, R.A. Bowman, and S.R. Olsen. 1979. Plant toxicity and soil transformations of soil-incorporated sulfur compounds. Final Report, U.S. Army Medical Research and Development Command Project Order 7615, U.S. Department of Agriculture, Agricultural Research-Western Region, Colorado-Wyoming Area, Fort Collins, CO.

48. Lyman, W.J. 1980. Research; and development methods for estimating physico-chemical properties of organic compounds of environmental concern. Monthly Progress Report #19, Contract No. DAMD 17-78-C-8073, Arthur D. Little, Inc., Cambridge, MA.

49. Occupational Safety and Health Administration Standard for Occupational Exposure to Lead (Executive Summary). 1978. In Chemical Regulation Report, Current Reports, 2(33):1434-1464.

50. Chaney, R.L. and H.W. Mielke. 1980. Evaluation of risk from Pb and other heavy metals present in urban garden and small farm soils. Progress Report, Biological Waste Management and Organic Resources Laboratory, AR, Beltsville Agricultural Research Center, Beltsville, MD.

51. Botts, R.P. 1977. The short-term effects of lead on domestic and wild animals. EPA-600/3-77-009, Ecological Research Series, Environmental Research Laboratory, Office of Research and Development, US Environmental Protection Agency, Corvallis, OR.

52. Lynch, G.P., D.G. Cornell, and D.F. Smith. 1974. Excretion of cadmium and lead into milk. in Trace Element Metabolism in Animals - 2, W.G. Hoekstra, J.W. Suttie, H.E. Ganther, and W. Mertz, eds., University Park Press, Baltimore, MD. pp. 470-472.

53. Mitchell, D.G. and R.M. Aldous. 1974. Lead content of foodstuffs. Environ. Health Perspectives 7:59-64.

54. Oehme, F.W. 9 October 1980. Personal Communition. Kansas State University, Manhattan, KA.

55. Scharding, N.W. and F.W. Oehme. 1973. The use of animal models for comparative studies of lead poisoning. Clin. Toxicol. 6(3):419-424.

56. Sisson, S. and J.D. Grossman. 1955. The Anatomy of the Domestic Animals, 4th Edition, revised, W.B. Saunders Co.

57. Chemical Engineer's Handbook. 1963.* Perry, R.H., C.H. Chilton, and S.D. Kilpatrick, eds., McGraw-Hill Book Company, Inc., New York, NY.

* Document is revised periodically. Cited reference used in study.

GLOSSARY OF ABBREVIATIONS AND SYMBOLS

Acronyms

ADI	Acceptable Daily Intake
DNT	Dinitrotoluene
PPLV	Preliminary Pollution Limit Value
SPPPLV	Single-pathway PPLV
TLV	Threshold Limit Value
TNB	1,3,5-Trinitrobenzene
TNT	2,4,6-Trinitrotoluene
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency

Symbols (Equation where first definition cited)

A1 (26)	Term to account for lead-content in milk associated with animal consumption of plant matter, μg Pb/kg milk
A2 (26)	Term to account for proportionate lead-content in milk as a functioning soil-lead content, μg Pb/kg milk per per mg Pb/kg dry soil.
AL (30)	Lifetime lead accumulation, mg Pb
B (27)	Proportionality constant to determine A1 and A2 from background lead-milk and lead-soil data, μg Pb/kg milk per mg Pb/day ingested
BF (13)	Bioaccumulation factor of a substance, mg/kg adipose tissue per mg/kg dry plant weight
BWA (1)	Adult body weight, kg
BWC (12)	Child body weight, kg
C_{sf} (6)	PPLV, mg pollutant/kg dry soil
C_{si} (3)	Single-pathway PPLV for numbered pathway "i", mg substance/kg dry soil
D_T (1)	Acceptable daily dose for humnans, mg substance/kg body weight/day
D_{Ti} (5)	Portion of acceptable daily dose transmitted via pathway "i"
D_T' (22)	Acceptable daily dose to workers for dust inhalation pathway
DC (11)	Dairy products consumption per capita, kg/day
FA (14)	Fraction fat in adipose tissue
IF (3)	Pollutant intake factor for a specific pathway

K_i (3) Partition coefficient for pollutant between soil and matter ingested by man

K_{ad} (11) Partition coefficient for a pollutant between animal fat and animal milk-fat, mg/kg milk per mg/kg animal fat

K_{pa} (10) Partition coefficient for a pollutant between plant (forage) material and meat, mg/kg meat per mg/kg dry plant weight

K_{sp} (9) Partition coefficient for a pollutant between soil and plant material, mg/kg dry plant weight per mg/kg dry soil

L(item) (26) Lead content in consumed item μg/kg

LC (29) Cattle intake of lead, mg/day

LD (35) Deer intake of lead, mg/day

LS (26) Lead content in animal or child-ingested soil, mg/kg dry soils

MC (10) Meat consumption per capita, kg/day

OC (A-1) Organic substance uptake by cattle, mg/day

PO (A-1) Plant organic substance content, mg/kg dry plant weight

R (*) Risk

R_i (4) Proportionality factor to relate C_{si} to D_T

RB′ (1) Adult workday air volume inhaled, m^3

SO (A-1) Soil organic substance content, mg/kg dry soil

SS (13) Solubility of organic substance in water, μg/L

VC (9) Vegetable consumption per capita, kg dry plant weight/day

XM (31) Lead content in muscle, μg/kg

* Page 6.

APPENDIX A

SOIL INGESTION BY CATTLE: ORGANIC SUBSTANCES

The ingested organic substance/day is given by

$$OC = (16.5 \text{ kg/day}) \times PO + (0.72 \text{ kg/day}) \times SO \qquad \text{(A-1)}$$

where OC = organic uptake/day, PO and SO are the organic content in plant and soil, respectively. With the assumption that $K_{sp} = 1$, Equation A-1 becomes

$$OC = 16.5 \times SO + 0.72 \times SO \qquad \text{(A-2)}$$

For cattle, the plant-derived intake of organic is 16.5/0.72 or 23 times that from soil. Thus, in PPLV computations where Pathway 1 or 2 are the critical pathways, neglecting soil leads to a maximum overestimate of the PPLV by 4.3%. When these pathways have little importance, the overall effect is less.

DISTRIBUTION LIST

No. of Copies	
5	US Army Medical Research and Development Command ATTN: SGRD-RMS Fort Detrick, Frederick, MD 21701
12	Defense Technical Information Center (DTIC) ATTN: DTIC-DDA Cameron Station Alexandria, VA 22314
1	Commandant Academy of Health Sciences, US Army ATTN: AHS-COM Fort Sam Houston, TX 78234
2	Librarian US Army Medical Bioengineering Research and Development Laboratory ATTN: SGRD-UBD-A Fort Detrick, Frederick, MD 21701

APPENDIX C

Determination of Flammability Limit for NC in Soil

EPA CHARACTERISTIC OF IGNITABILITY

The EPA characteristic of ignitability for solid wastes is defined in 40 CFR Part 261.21 as follows:

"A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:

1. It is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume, and has a flash point less than 60°C (140°F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM Standard D-93-79, or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D-3278-78, or as determined by an equivalent test method approved by the Administrator under the procedures set forth in Sections 260.20 and 260.21.

2. It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.

3. It is an ignitable compressed gas as defined in 49 CFR 173.300 and as determined by the test methods described in that regulation or equivalent test methods approved by the Administrator under Sections 260.20 and 260.21.

4. It is an oxidizer as defined in 49 CFR 173.151.

A solid waste that exhibits the characteristic of ignitability, but is not listed as a hazardous waste in Subpart D, has the EPA Hazardous Waste Number of D001."

METHOD FOR TESTING IGNITABILITY OF NITROCELLULOSE/SOIL MIXTURES

1. Nitrocellulose (NC) was dried in petri dishes in a desiccator (silica gel) until it was fluffy and did not stick together. This required 1 and 4 days, respectively, for the 12.66% and the 13.2% NC (percent by weight nitrogen).

2. Dry soil from behind EMSC was seived through a No. 4, a No. 6, and a No. 12 seive and dried in an oven at 124°C overnight. The seive mesh sizes were:

   No. 4 — 0.187 in.
   No. 6 — 0.132 in.
   No. 12 — 0.055 in.

3. Appropriate amounts of NC and soil (cooled in desiccator) were weighed out so that the total weight was ∿1/2 to 2 g.

4. The mixtures were shaken vigorously in 25 ml screw-cap glass vials until thoroughly mixed, i.e., until color and consistency were homogeneous. Solvent was not used to aid in dispersing the NC as this does not simulate natural conditions.

5. The sample was emptied onto a sheet of paper and divided into four equal portions with a spatula. Each portion was placed in a 5-in. ribbed watch glass; two portions in piles and two portions spread out into a thin layer (∿1/8 in. deep). The mixture was left loose, not packed down.

6. The test flame (see next paragraph) was touched to the pile, and observations of the burning characteristics were recorded. The following specifics were noted:

a. Whether the sample burned, i.e., whether the test flame at least increased in size.

b. How long the sample continued to burn after the test flame was removed.

c. Whether the burning stayed on the surface or permeated the pile.

The flame exposure device from a Pensky-Martens Flash Point Tester (see ASTM D93-79) served as the ignition source. It is essentially a metal tube with a 0.027- to 0.031-in. orifice at the end and a needle valve for flame adjustment. The flame (natural gas) was adjusted to 5/32 in. in diameter as specified in ASTM 093-79.

RESULTS

Nitrogen (%)	NC (%)	Burn?	How long after flame gone?	Surface flame only?
12.7	12.3	Just charred	0 s	Yes
12.7	19.5	Yes	1 s	Yes
12.7	29.0	Yes	∿1 s	Yes
12.7	33.9	Yes	∿2 s	Yes
13.2	12.7	Just charred	0 s	Yes
13.2	16.8	Yes	<1 s	Yes
13.2	24.3	Yes	2-4 s	Yes
NA	0	No	-	-

*Only on the spread-out samples

CONCLUSIONS

It can be concluded that a 12 to 13% NC/soil mixture will not ignite. Since water reduces the flammability of the mixture and since the soil for these tests had been dried, the 12 to 13% figure represents a worst case.

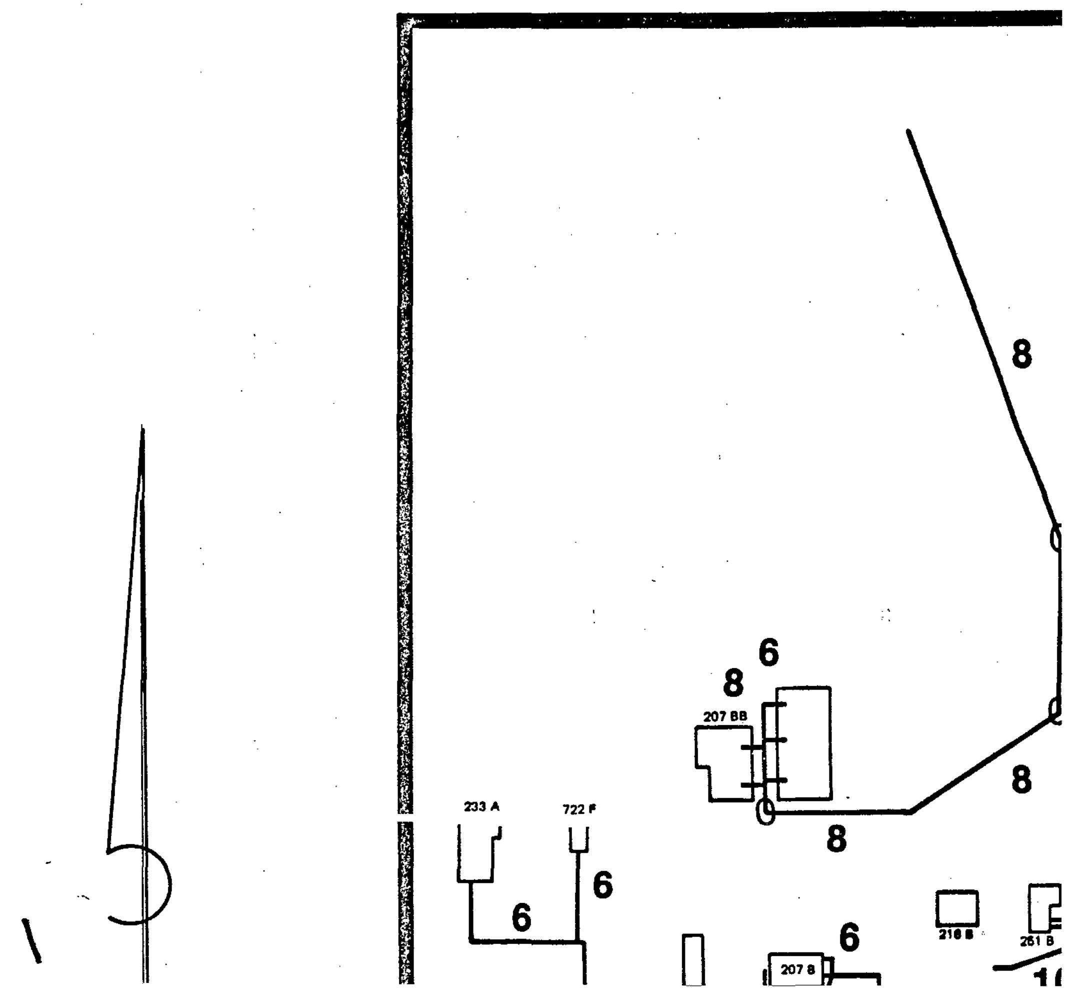
DISTRIBUTION LIST

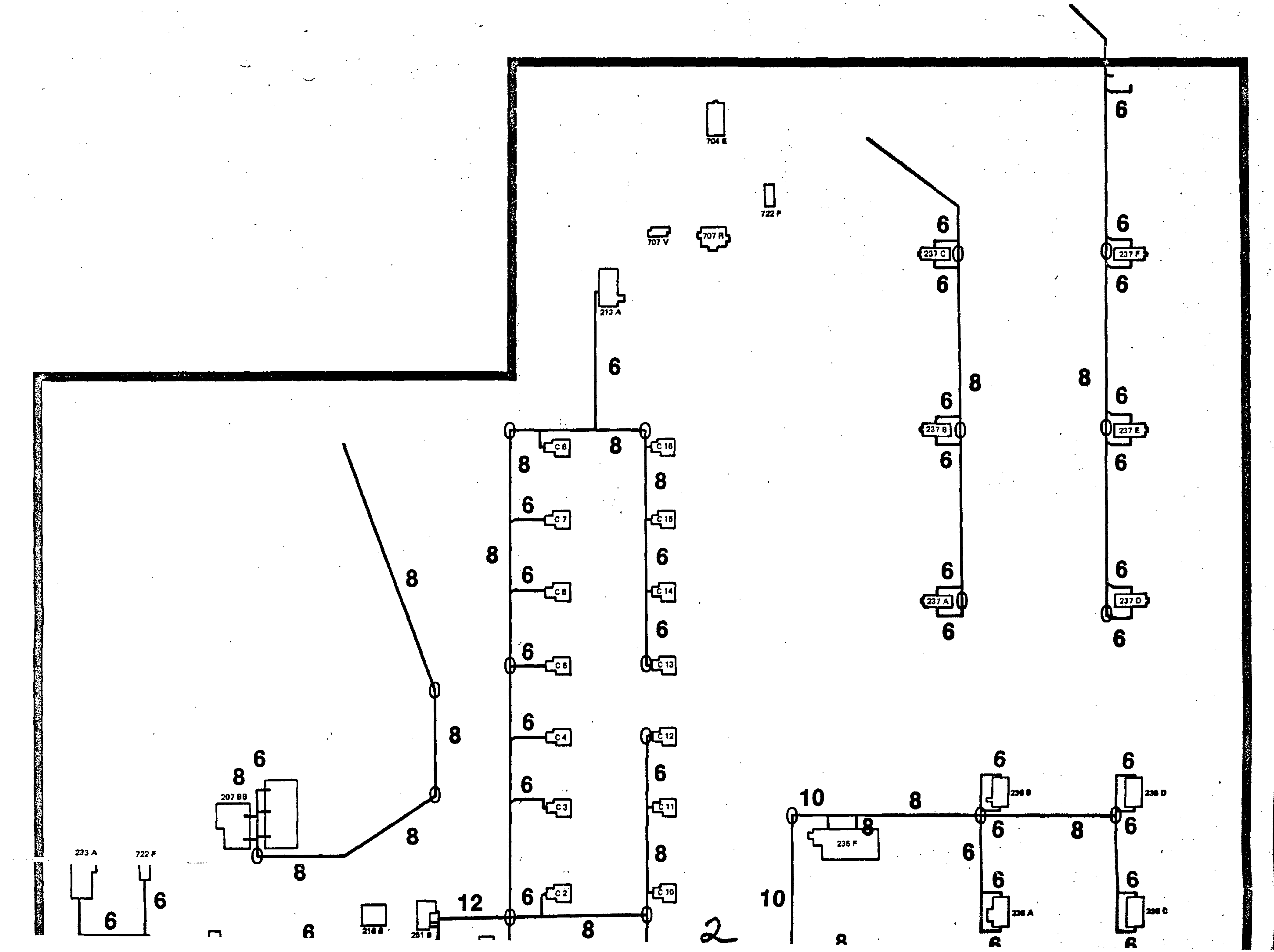
DRXTH-AS	(14 copies)
DRXTH-ES	(2 copies)
Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	(12 copies)
Defense Logistics Studies Information Exchange U.S. Army Logistics Management Center Fort Lee, Virginia 23801	(2 copies)

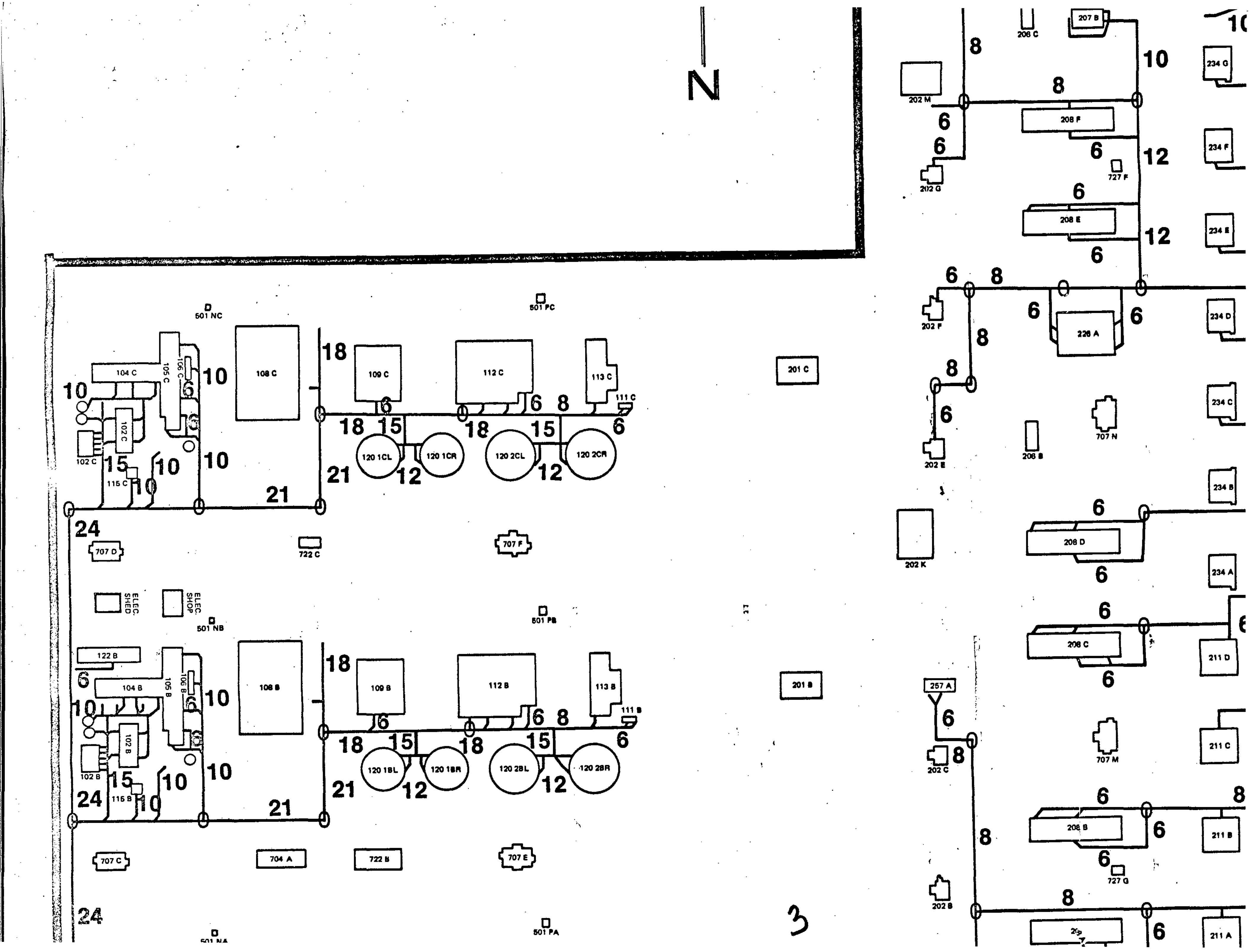
5056D-1jm

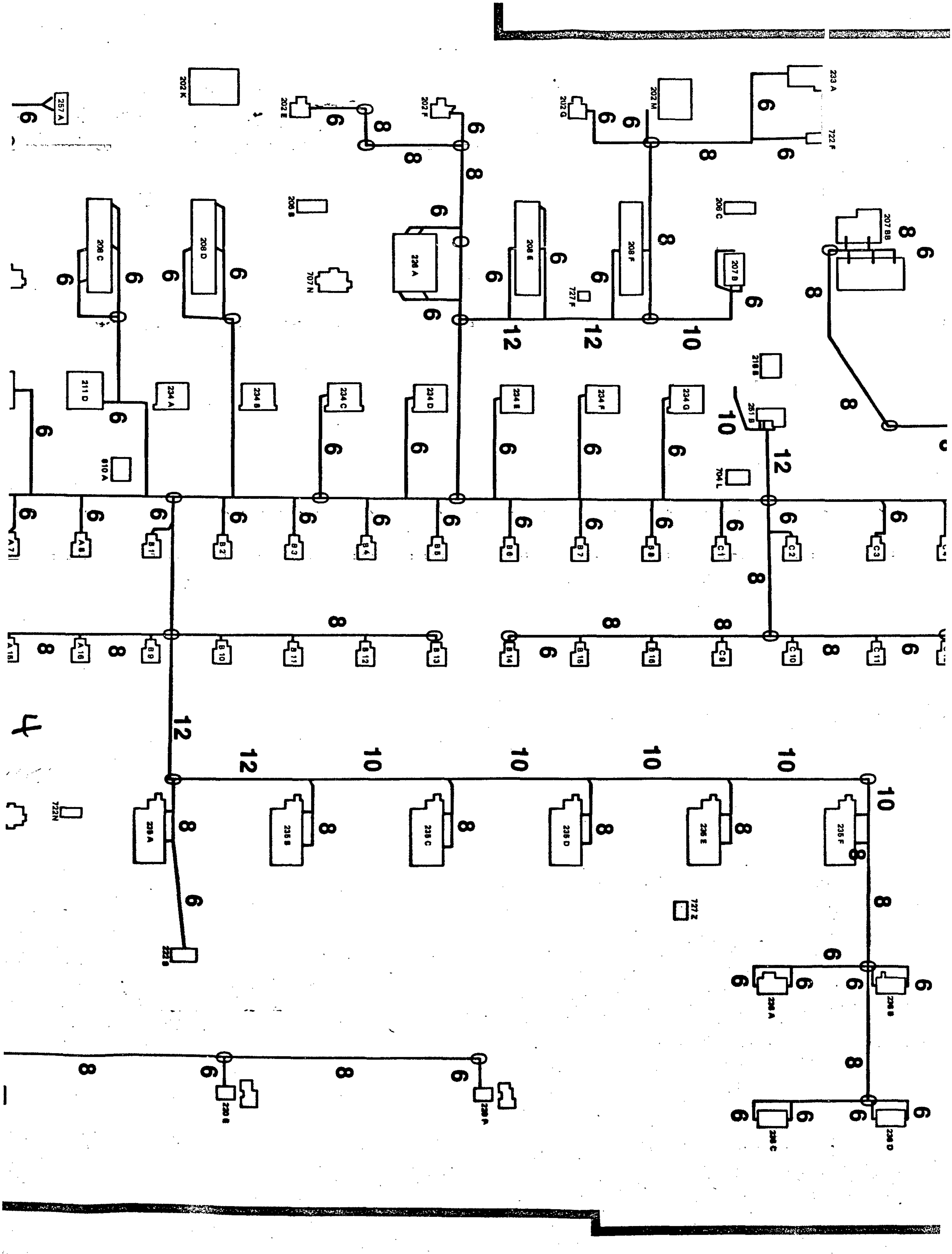
Figure 3

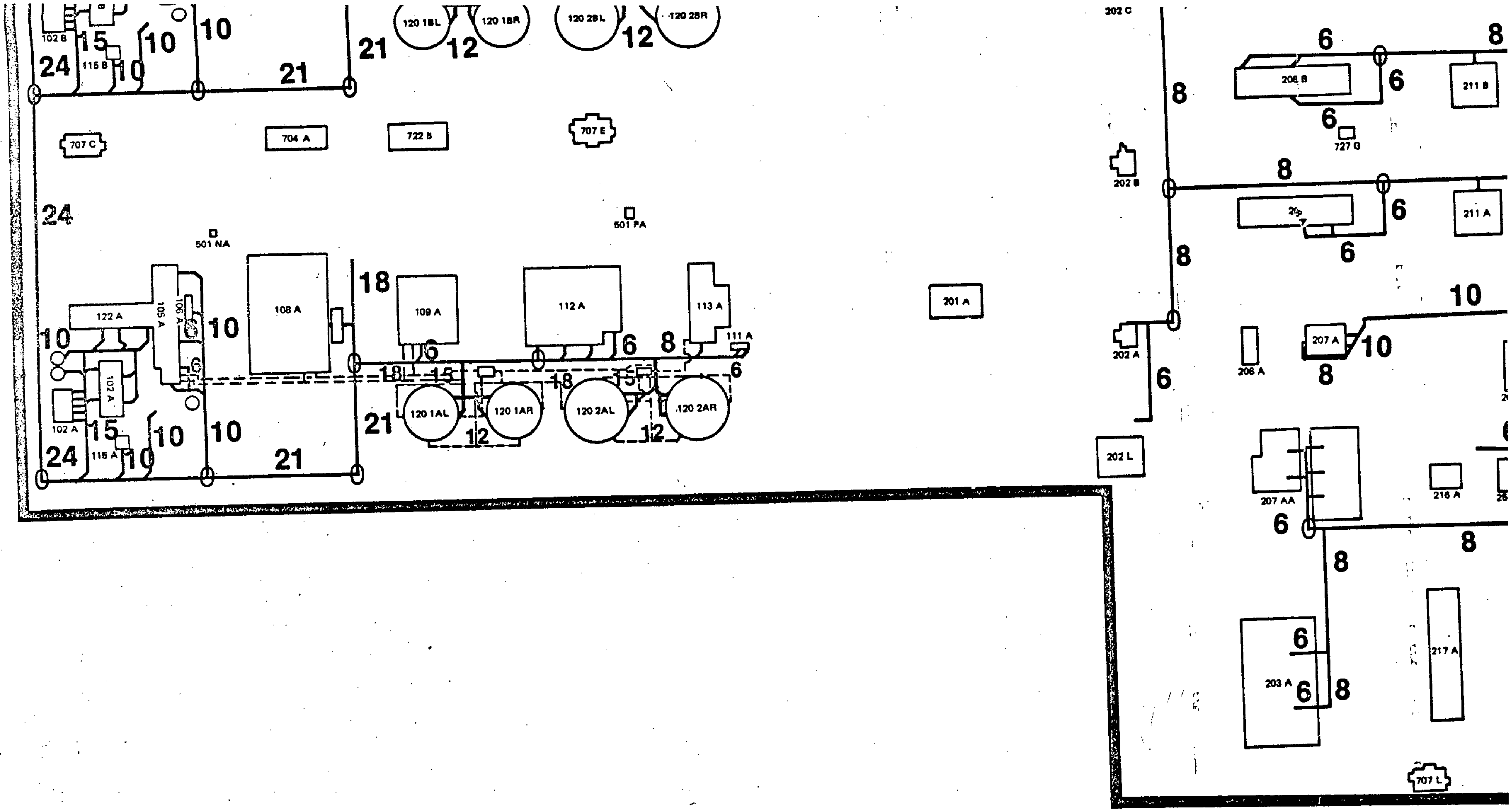
ALABAMA ARMY
AMMUNTION PLANT
LEASEBACK AREA




233 A
722 F
207 BB
C 2
C 3
C 4
C 5
C 6
C 7
C 8
C 10
C 11
C 12
C 13
C 14
C 15
C 16
213 A
707 V
707 R
704 E
722 P
235 F
236 A
236 B
236 C
236 D
237 A
237 B
237 C
237 D
237 E
237 F

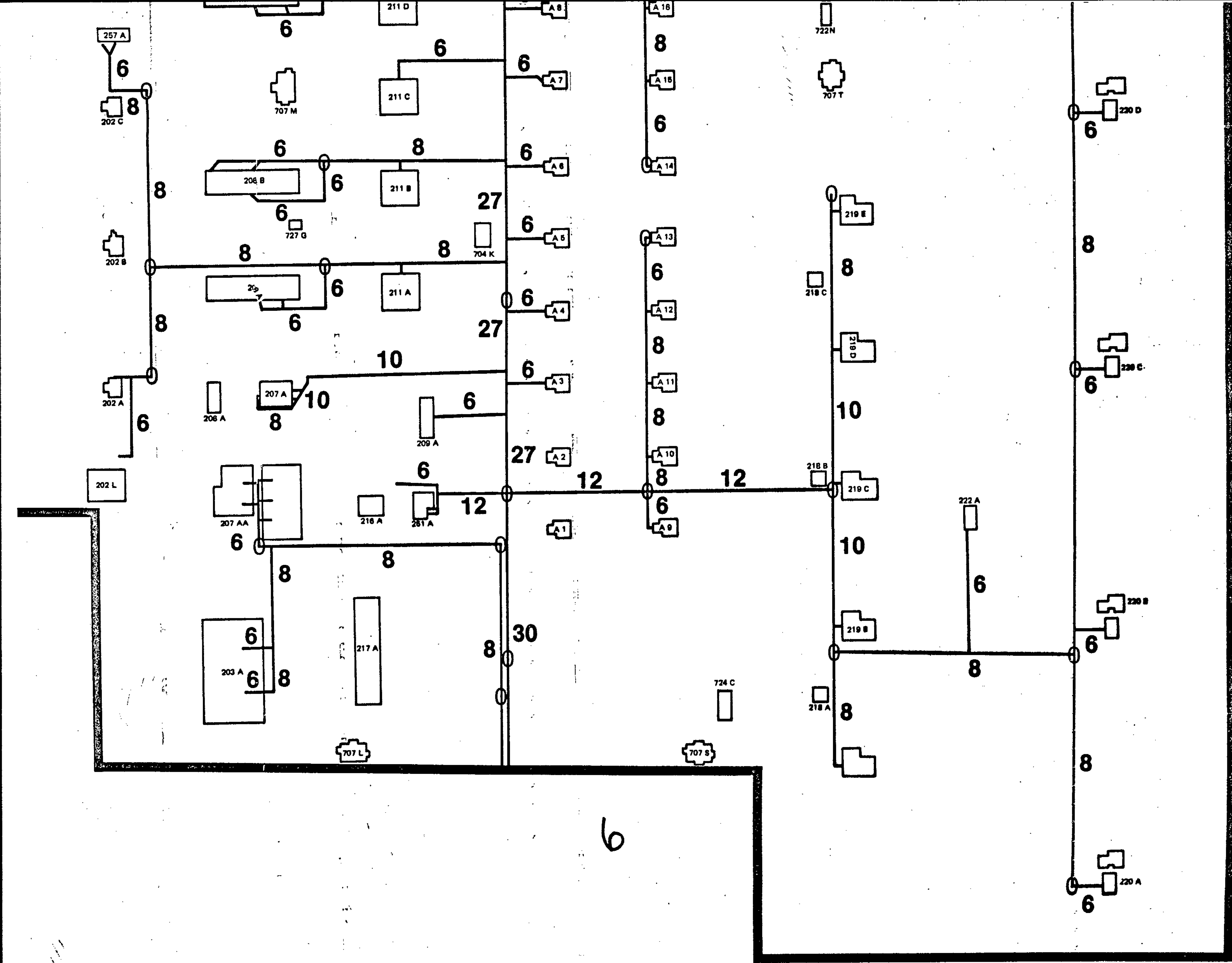

N
501 NC
501 PC
104 C
105 C
106 C
108 C
109 C
112 C
113 C
111 C
102 C
115 C
120 1CL
120 1CR
120 2CL
120 2CR
707 D
722 C
707 F
201 C
ELEC. SHED
ELEC. SHOP
501 NB
501 PB
122 B
104 B
105 B
106 B
108 B
109 B
112 B
113 B
111 B
102 B
116 B
120 1BL
120 1BR
120 2BL
120 2BR
201 B
707 C
704 A
722 B
707 E
501 NA
501 PA
3
207 B
206 C
202 M
208 F
202 G
727 F
208 E
202 F
226 A
202 E
206 B
707 N
202 K
208 D
208 C
257 A
202 C
707 M
208 B
727 G
202 B
234 G
234 F
234 E
234 D
234 C
234 B
234 A
211 D
211 C
211 B
211 A


257 A
202 K
202 E
202 F
202 G
202 M
233 A
722 F
206 B
206 C
207 BB
208 C
208 D
208 E
208 F
226 A
707 N
727 F
207 B
211 D
234 A
234 B
234 C
234 D
234 E
234 F
234 G
216 B
251 B
810 A
704 L
B 1
B 2
B 3
B 4
B 5
B 6
B 7
B 8
C 1
C 2
C 3
A 16
B 9
B 10
B 11
B 12
B 13
B 14
B 15
B 16
C 9
C 10
C 11
722N
235 A
235 B
235 C
235 D
235 E
235 F
727 Z
222 B
236 A
236 B
236 C
236 D
220 B
220 A
4



102 B
115 B
707 C
704 A
722 B
707 E
120 1BL
120 1BR
120 2BL
120 2BR
501 NA
501 PA
122 A
105 A
106 A
108 A
109 A
112 A
113 A
111 A
102 A
115 A
120 1AL
120 1AR
120 2AL
120 2AR
201 A
202 C
202 B
202 A
202 L
208 B
727 G
211 B
211 A
206 A
207 A
207 AA
216 A
203 A
217 A
707 L

5



257 A
202 C
202 B
202 A
202 L
211 D
211 C
211 B
211 A
707 M
208 B
727 G
704 K
207 A
208 A
209 A
207 AA
216 A
201 A
203 A
217 A
707 L
707 S
724 C
A 1
A 2
A 3
A 4
A 5
A 6
A 7
A 8
A 9
A 10
A 11
A 12
A 13
A 14
A 15
A 16
722N
707 T
219 E
219 D
219 C
219 B
218 C
218 B
218 A
222 A
220 D
220 C
220 B
220 A
6